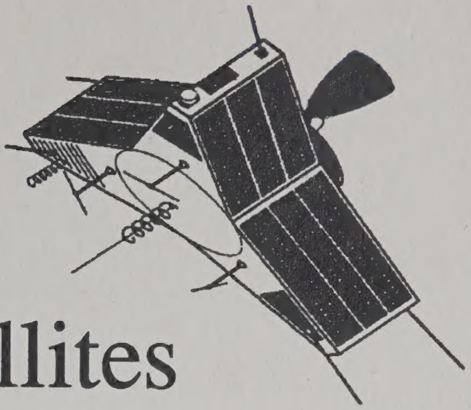
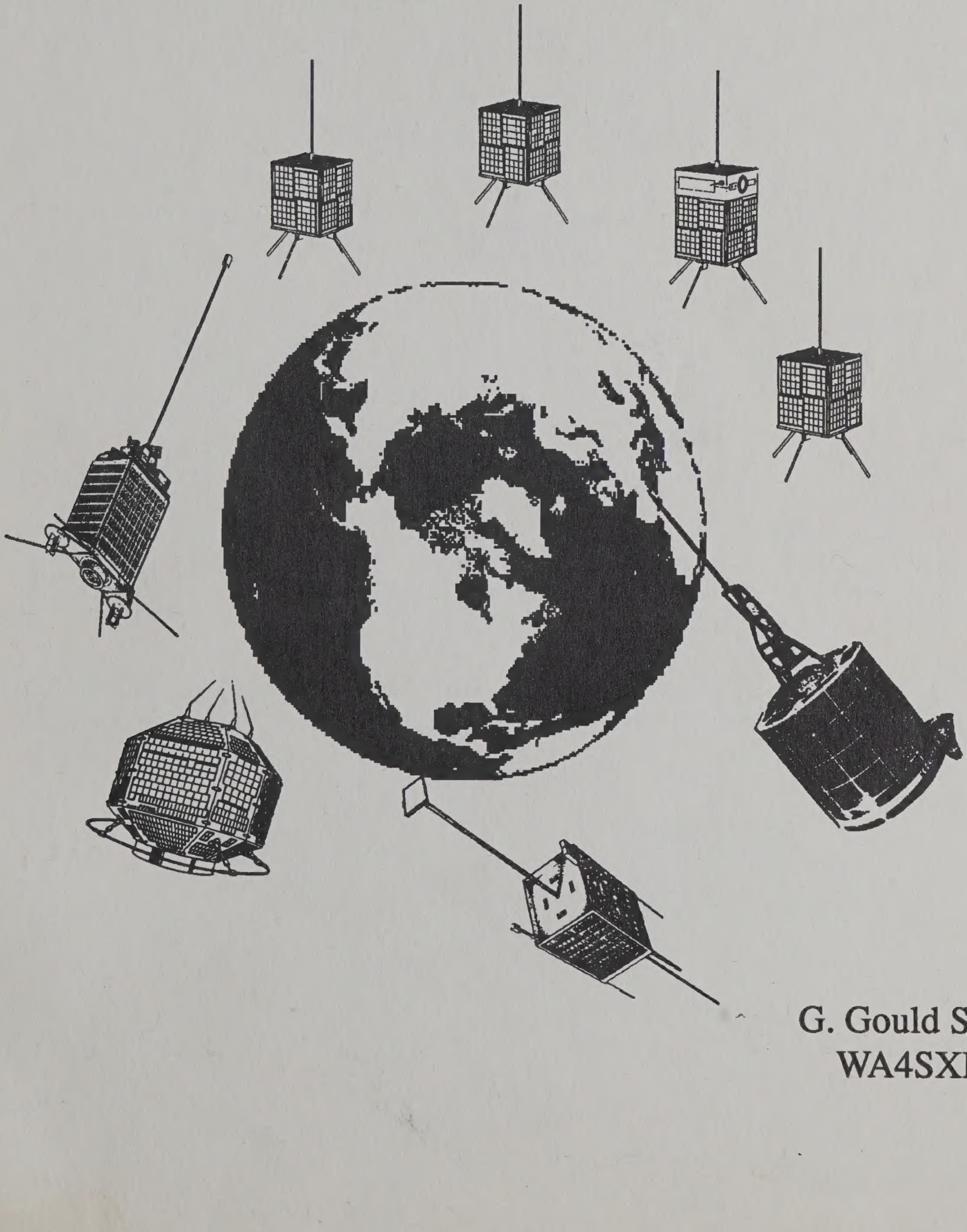
WD 4EUD



Decoding Telemetry from the Amateur Satellites



G. Gould Smith
WA4SXM

A Handbook of
Amateur Satellite Telemetry

by
G. Gould Smith
March 1991

Opinions expressed are those of the author and not necessarily those of AMSAT-NA.
Copyright (c) 1990 by G. Gould Smith. Rights to reproduce and sell this document are given to AMSAT-NA.

G. Gould Smith
8008 Chesterfield Dr.
Knoxville, TN 37909
WA4SXM @KT4F.TN.USA

Acknowledgements

I wish to thank all the authors referenced in the Bibliography for taking the time to explain a part of the amateur satellite field. My family for being patient for all those nights and weekends I worked on this handbook. Many thanks to Joe Kasser, Bruce Rahn and Courtney Duncan for their meticulous reading and insightful suggestions. To Dale Henkes for scanning the images, and James Miller for all the questions he promptly and thoroughly answered.

Gould Smith, WA4SXM

Introduction

The purpose of this document is provide a general reference source for amateur satellite telemetry. I am attempting to provide sufficient information for the motivated person to receive, capture and decode amateur satellite telemetry. Since I know that less than a handful of people will read this page, the information on this page will appear elsewhere in the document.

Receiving the telemetry
I list the necessary equipment to receive telemetry from each of the active amateur satellites. Interfacing the equipment is always the most difficult part of setting up a telemetry receiving station. Including descriptions of how to interface the many different types of equipment are not practical, given the number of combinations possible. Included are notes of problems I have encountered and the solution(s) implemented. I have used most of the available telemetry converting equipment and I have not had too much trouble getting it to work correctly. The main problem was not knowing what I was receiving. That is why I have done this handbook.

Capturing the telemetry
Methods of capturing the information are discussed. This generally involves storing the data in a file on your computer. Other than the digitized voice telemetry most of the other data formats can be stored digitally using a standard terminal program. The hardware conversion boxes do most of the work and output either an ASCII or hex data stream. It is a relatively simple matter to store the data. Many of the software decoding programs also have capture functions built-in.

Decoding the telemetry
A complete set of calibration/decoding equations for each of the active satellites is included. Examples of hand decoding most of the telemetry is also shown. The newer satellites send telemetry in formats that virtually require a computer to decode them. Hand decoding the telemetry is a good skill to learn, but once mastered, let a computer do it. Available decoding software is discussed and examples of the hardcopy or screen output is shown.

Assumed skills:

1) ability to interface the components;
2) ability to track a satellite;
3) familiarity with computer operation; and
4) competent operation of a satellite station

Conventions:

$ in front of a number means that it is hexadecimal
h as a suffix to a number also means that it is hexadecimal
0xDD is another hexadecimal representation
<> surrounding a character(s) means that they are ASCII characters
bit positions are numbered left to right 7 -> 0
The date at the top left of each page is the date the section was last edited.

Table of Contents

Telemetry .... 1-1 - 1-7

RS-10/11 .... 2-1 - 2-7

UO-11 .... 3-1 - 3-21

AO-13 .... 4-1 - 4-20

UO-14 .... 5-1 - 5-5

AO-16 .... 6-1 - 6-10

DO-17 .... 7-1 - 7-9

WO-18 .... 8-1 - 8-13

LO-19 .... 9-1 - 9-12

FO-20 .... 10-1 - 10-11

AO-21 .... 11-1 - 11-6

RS-12/13 .... 12-1 - 12-2

Appendices

ASCII A-1 - A-2

Telemetry Beacon Frequencies B-1 - B-2

Number Bases C-1 - C-5

WOD data and Microsat TRACEs D-1 - D-10

Construction and Alignment notes E-1 - E-3

Bibliography F-1 - F-4

Glossary G-1 - G-4

CRC and checksums H-1 - H-3

Product sources I-1 - I-2

Telemetry Archive J-1 - J-2

Command Station Development Program K-1 - K-3

February 25, 1991

Telemetry

The word TELEMETRY is derived from the Greek words 'tele' and 'meter', together they mean to measure from afar. Telemetry data from amateur satellites has been available since 1961. OSCAR I repetitively sent the CW message 'HI' at a speed related to the internal temperature of the spacecraft. The information received from this simple telemetry resulted in changes to the thermal coating and a lowering of the transmitter power for OSCAR II. The primary purpose of telemetry is to monitor, encode, transmit, and decode data concerning the vital systems of the satellite. The telemetry information gleaned from earlier satellites has contributes to the design of more reliable, longer lasting and fuller featured satellites.

Telemetry has two definitions. The most common usage refers to the 3 step process of:

1) converting analog data to digital data;
2) transmission of the digital data; and
3) conversion of the received signal into a usable form.

The other definition refers to the actual data itself. This dual definition often causes confusion when discussing telemetry.

Telemetry determinations

Telemetry is one of the major components of a modern satellite system. The complete system includes:

1) the power system;
2) the On Board Computer (OBC);
3) the Attitude control system;
4) the Transmitter;
5) the Receiver;
6) the Telemetry system;
7) and any on board experiments or transponders.

A satellite is a self-contained system that must be able to sustain its own existence. Unlike terrestrial systems, problems can't be diagnosed and corrected on the work bench. A satellite is an 'ecosystem'. It must generate enough power to stay functional and apportion this power to the most critical systems when necessary. It must be able to regulate its temperature so as not to stress the mechanical structure and to maintain the electronics and batteries in their operational ranges. The system must be kept in equilibrium or it will quickly fail. Ideally all combinations of possible problems have been anticipated and solutions formulated before the satellite is deployed. This is an unattainable objective. The most reasonable alternative is to monitor the critical systems and provide a means to alter the operation of the satellite from the ground to correct the un-anticipated problems. This too is a lofty objective, but the most practical. Determining the proper points to monitor, analyzing the telemetry, and using this analysis to keep the system in harmony will give the satellite its full controllable lifetime. Knowledge gained from each satellite is then used on the next generation of satellites to make them more self-regulating. Telemetry must monitor all the major systems and send this data to the ground command stations in a timely manner. When any component of the system is not functioning properly, the problem must be quickly corrected, as all the systems depend upon one another.

Telemetry generally measures four quantities: temperature, current, voltage and status. The first three describe the analog portion of the system. The fourth is necessary to communicate the state of a device. Is it ON or OFF, selected or not selected? The major components of the satellite offer many sources of analog and digital values to be sampled. It is the difficult job of the system designers to choose:

1) which values are to be monitored;
2) what mode of transmission is to be used;
3) how the data is to be encoded;
4) how much error detection to use;
5) how often to send the telemetry;
6) how much power to allocate to the transmission;
7) at what rate to send the data;
8) how much memory can be allocated;
9) how complex a ground station is needed;
10) how to readjust the system via ground command;

A General Telemetry Model

A telemetry **frame** is the unit used to describe the collection of all the sampled points. The general frame is comprised of a group of attention characters, the header, all the data channels, the checksum. Most of the telemetry from amateur satellites contain all of these features. The telemetry samples found in Figure 1.1 are to be used as examples for the following descriptions of the major sections of a telemetry frame. The specific decoding of the frames is done in the chapter on that particular satellite.

Attention/synchronization characters

Attention characters are a sequence of characters used to signal the beginning of a new frame. When a receiving station begins to acquire satellite telemetry it has no way of knowing where in the data stream it is. Odds are it is in the middle of a frame. The attention characters tell the receiving system to start anew, to clear its buffer and begin a new frame sequence. AO-13 in PSK mode uses the ASCII sequence 39h, 15h, EDh, 30h, and in RTTY mode the traditional RYRYRYRYRY's. Many satellites use the 'HI HI' sequence in CW and ASCII mode.

Header line

The header line follows the attention characters. It normally identifies the satellite and contains some type of date/time group. The time that the data was sampled by the microprocessor is as important as the data itself. When analyzing the data it is necessary to know or be able to find out things like: whether the sun was shining on the satellite or not; what mode the satellite was in; or where the satellite was in its orbit. UTC is used for both the time and the date for all the amateur satellites. The DOVE header line identifies the spacecraft, tells how long the current software has been running and gives the current UTC date and time. The AO-13 header line gives generally the same information, but adds a block or frame type. Often the date or both the date and time is coded to save memory space. It requires less power to transmit shorter data sequences. The decoding of the encrypted date/time groups for each satellite is covered in the format descriptions of the individual satellites.

Channel data

This is the main objective for the telemetry transmission. These data points sample either analog or digital data. Analog data measures temperature, pressure, current, or the voltage present at that point. Digital data defines the state of that point. An individual data point is referred to as a channel. An analog to digital converter (ADC) is used to convert the pressure, temperature, current or voltage to a digital value that the On Board Computer (OBC) can store. Each ADC reads the analog value of a sensor a little differently, so it is necessary to calibrate each sensor/ADC connection. The state is a binary value that defines one of two states of a particular point. In about half of the amateur satellite telemetry data formats the channel number is attached to the data. This is helpful in locating specific data and as a check. It does almost double the amount of the telemetry data transmitted, thus using quite a bit of energy to transmit the extra characters. The actual data is transmitted as either a decimal, hexadecimal, octal or binary value. Different number bases are used by all of the amateur satellites. Often one satellite will send data in a variety of different number bases in a single frame. These are consistent and documented, so as long you have the correct documentation, decoding should be a trivial exercise. Each channel has a specific calibration equation. These calibration equations are initially calculated on the ground for each channel prior to launch. So when the data for each channel is received it must be normalized by its own calibration equation to give the true value of the channel measured. In addition to the analog data, status data is sent in the telemetry channels. Status is a binary function (0 or 1). These represent TRUE or FALSE, ON or OFF or two defined selections like PROM or RAM. In the interest of efficiency the status points are usually transmitted as hexadecimal or octal values. These are then broken down by bit position after the telemetry is received. The state of each status function is then assigned by the 1 or 0 value in that bit position. See the telemetry decoding examples in the chapters on UO-11 or AO-13 for a specific illustration of status decoding.

Checksum

A checksum is used to validate the data. The name comes from a summing of the data as it is received, then a comparison of this sum to the sum calculated before transmission. The received data is useless unless it is valid. An even worse situation exists if erroneous data is considered valid and incorrect decisions are made because of this error. Some level of error checking is necessary, the difficult decision is how much to use. There are a number of different methods that give varying degrees of validity to the data. Some are simple to implement and have only a 60% chance of catching the error. on the other extreme some error checking schemes require more bits than the data it is validating. Others require complex mathematical formulas. Obviously there has to be some middle ground that gives a reasonable level of integrity without using a large number of characters. Normally the checksum is either some type of straight sum or XOR/EOR (EXclusive OR) of the data. The checksum either passes and the data is valid, or fails and the data is invalid. The checksum can be attached to each channel, line or encompass the entire frame. Telemetry sent in AX.25 packets have the checksum as part of the packet. Appendix H goes into more depth.

Figure 1.1 Sample telemetry frames from DOVE, UO-11, AO-13 and FO-20.

```
DOVE-1>TIME-1:PHT: uptime is 001/01:10:22.  Time is Mon Jul 23 03:52:18 1990

DOVE-1>TLM:00:59 01:58 02:88 03:30 04:56 05:56 06:6F 07:49 08:6C 09:6A 0A:A2
0B:DC 0C:E8 0D:D6 0E:00 0F:24 10:C8 11:88 12:00 13:01 14:B5 15:A3
16:9B 17:9A 18:9C 19:9B 1A:98 1B:94 1C:A0 1D:9C 1E:21 1F:5D 20:BC

DOVE-1>TLM:21:8E 22:78 23:1C 24:1C 25:35 26:00 27:00 28:00 29:00 2A:00 2B:00
2C:00 2D:30 2E:00 2F:A4 30:D2 31:A4 32:06 33:28 34:CA 35:AA 36:B1
37:B0 38:BF 39:85 3A:87

DOVE-1>STATUS: 80 00 00 85 B0 18 55 02 00 30 00 00 09 0B 3C 05 29 5A 03 04
DOVE-1>LSTAT:I P:0x3000 o:0 l:13081 f:13081, d:0

DOVE-1>WASH:wash addr:3640:0000, edac=0x3f
```

```
                ===================================
```

```
UOSAT-2                9008046141320

00516201395E02232103572304053205037106020407052008045909040D
10498411335512000313066214070215506716186817490B18483619524B
20514221224722660023000124000625000726095827469E28474D29499F
30274231036732285E33573134007035273036321537428A38470839505A
40765041120642642643062344167045000146000247490E48505C49475B
50547351107252682B536891546623550000560003574978584922594954
6083E3615FC1625F4A633305644402651E0C661B4E67700668000E69000F
```

```
                ===================================
```

```
Q  HI, THIS IS AMSAT OSCAR 13                   02:39:31  4581
#0026   #0020   #017A
64  9  0  1  17  230  0

 193   7 152   7 193   7 165 115 200   7 136   7 100   7 153  29
   7   7 138  54   9   7 136 136  16   7 139 151 116   7 137   7
 147 134 136   7 220 149 134   7  75 149 134 165 227 132 127  55
 179 133 139  94 146 144 138   7  13 141 125   7 208 140 132   7
  64   9   0   1  17 230   0   0  10   3 105  84   5  40  65  32
  65   0 152   0 148   0  38  55   0 205   3   5   0   0  32   0
   0 250   0 100  14 210  65   6  14  33  39   2 229  17   1   0
   0   0   1   0   0   0   1   0   0   0   1   0  38   0  17   0
```

```
                ===================================
```

```
8J1JBS>BEACON:JAS1b RA 90/05/07 03:49:58
427 453 669 678 729 836 847 829 001 660
617 000 498 497 521 516 519 522 654 000
644 644 644 619 999 646 879 485 026 010
010 111 100 000 111 100 101 110 010 000
```

Telemetry decoding for specific amateur satellites

Each of the active satellites has an entire chapter devoted to explaining the telemetry transmitted from that satellite. Included in each chapter is:

1) the equipment necessary to receive the telemetry;
2) a thorough description of the telemetry format;
3) a table of calibration equations for the analog data;
4) a table of status point definitions;
4) actual telemetry data from the satellite;
5) examples of hand decoding the telemetry; and
5) descriptions and output examples of the available telemetry decoding software;

The appendix contains:

1) operational or construction hints for many of the decoding units;
2) an amateur satellite telemetry glossary;
3) amateur satellite telemetry bibliography;
4) sources for telemetry equipment and software;
5) telemetry beacon frequencies and the associated transmission modes;
6) brief discussion on checksums;
7) information on telemetry archive;
8) description of the Command Station Development Program;
8) explanation of ASCII data; and
9) hexadecimal, octal, binary and decimal conversion table.

Telemetry complexity

I have divided the telemetry from the active satellites into 8 categories based upon the complexity of the reception/decoding requirements. Depending upon your interest, resources and skill these categories should give you some idea of what to expect. These are listed in order of simplest to more complex.

1) Digitized speech	UO-11, DO-17
2) CW	RS-10/11, AO-13, FO-20, LO-19, AO-21, RS-12/13
3) RTTY	AO-13, AO-21
4) 1200 bps AFSK packet	DO-17
5) 1200 bps AFSK ASCII	UO-11
6) 1200 bps PSK 8 bit packet	AO-16, WO-18, LO-19, FO-20, AO-21
7) 400 bps PSK ASCII	AO-13, AO-21
8) 9600 bps FSK ASCII	UO-14

1. Digitized speech telemetry

Digitized speech telemetry has the simplest requirements for both equipment and operator skill of all amateur satellite telemetry. It also is the least efficient (data rate/time), has the least resolution and is the most prone to error. It is transmitted as an educational tool and to interest people in satellite activities. Data values from each channel are already calibrated when spoken, so writing down the data for each channel is all that is required. Digitized speech offers a fun, simple way to pursue an interest or to interest others in satellite operation.

2. CW telemetry

Reception equipment requirements for CW telemetry are minimal, but require more operator skill to receive the telemetry than the digitized speech telemetry. The data resolution is not as high as the other telemetry formats and no error checking is used. Most of the CW telemetry transmissions don't transmit the date/time group or label each channel. It is up to the operator to add the date/time group to any CW telemetry received. Data values for each channel must be calibrated using a specific calibration equation. Each satellite has its own set of calibrations equations for each channel. CW telemetry on the later(post 1987) satellites is transmitted more in deference to tradition than as a efficient method of satellite monitoring.

3. RTTY telemetry

AO-13 currently is the only amateur satellite that routinely transmits telemetry in RTTY. Many amateur stations have RTTY units and VHF/UHF SSB receivers or converters so reception is fairly easy. This mode is more efficient in terms of number of characters per unit time than speech or CW, but still has many of the limitations. RTTY on AO-13 was implemented more to make telemetry data available to general amateurs than as a primary telemetry mode.

4. 1200 bps AFSK packet telemetry

The next step up is the AFSK packet AX.25 telemetry. The data can be collected with a standard 2M FM receiver and 1200 bps AFSK packet TNC. The signal from DOVE is strong and the equipment is readily available or in place. Efficient transfer, error checking, and a large number of stations already equipped to receive the data make this a very good telemetry format.

5. 1200 bps AFSK ASCII telemetry

This format utilizes the simple modulation scheme of sending ASCII data by shifting between 1200 and 2400 Hz to convey the 1's and 0's. This ASCII data comes down at 1200 baud and can be copied by a standard Bell 202 modem that has a slight modification(the bit sense will need to be reversed). This format has been around for quite awhile so their is a fair amount of equipment available. High signal/low noise levels are important for this digital data, so a good receiving station is needed. Station requirements include the ability to track the satellite from horizon to horizon in order to maintain a strong signal. The specialized equipment and station requirements put this format at number 5.

6. 1200 bps PSK packet telemetry

The telemetry format of choice for the Microsats and FO-20 is 1200 bps PSK packet. This form has evolved to be among the most efficient and complex to decode. The range of equipment needed and the skill of the operator are also among the most advanced. This challenging aspect of the hobby is what makes it interesting for many of us. The data is sent as 8 bit hex and ASCII frames interspersed between the packet BBS or other binary data download. The equipment needed to receive the Microsats and FO-20 is actually the same equipment used for FO-12. It's not always necessary to re-equip the station for each new satellite. The microsats utilize a complex and very configurable design, the system allows the telemetry format to be changed as needed. The information presented here is currently correct, but may become outdated. This document will be revised to stay current with the telemetry formats. The receiving hardware should stay the same and only changes made in the decoding software.

7. 400 bps PSK ASCII telemetry

This is the predominant form of telemetry on AO-13, in use for 40 minutes out of each hour. The station complexity increases a great deal here because a specialized piece of equipment is needed and a good receiving station is mandatory. The operator skills required are the ability to track the satellite and tune in the signal. The telemetry from AO-13 is extensive and efficient. AO-21(RS-14) also has the capability to utilize this data format.

Why PSK?

Audio Frequency Shift Keying (AFSK) was the modulation of choice for the early LEO (Low Earth Orbit) satellites. The modulation generally shifts between 2 tones, nominally 1200 and 2400 Hz to send data. One tone was interpreted as a 0 the other as a 1. Since these satellites were relatively close to the earth, a strong signal could be received on common FM or SSB equipment. With the advent of amateur satellites with highly elliptical orbits, telemetry could not be allocated enough power to transmit a strong signal from 40,000 km. A more power efficient method was needed, PSK was the answer. Phase Shift Keying (PSK) simply changes the phase angle of the carrier modulation to encode the data bits. A smaller bandwidth requirement and a lower bit error rate/power used are its two best features. Bit error rates are the number of incorrect data bits detected in a character stream. If we receive two signals having equal bit error rates, one utilizing AFSK modulation and the other PSK modulation, the PSK signal can have a 4dB lower signal to noise level than the AFSK transmission. This means that a PSK modulated transmission can be made at half the power of a comparable AFSK modulated transmission. Said again, a PSK modulated signal could offer an equal data recovery rate with less than half the received signal strength of an AFSK modulated signal. So obviously PSK modulation was chosen for these new satellites. The same advantages of PSK modulation that are demonstrated for satellites are also applicable to terrestrial operation. AO-10, FO-12, AO-13, the Microsats, and FO-20 all use this form of data modulation. A occasional complaint voiced about the choice of this modulation scheme is that it causes those interested in telemetry reception to build/purchase a new piece of equipment. The PSK scheme was chosen because it was the proper engineering choice. It offers a more efficient way to transmit data from the satellites. Not to mention that it is educational and advances the technology. Using PSK modulation should also enhance terrestrial packet operation, both VHF and HF.

8. 9600 bps FSK ASCII telemetry

Currently the UO-14 9600 bps FSK telemetry is the most complex form of amateur satellite telemetry. Data sent at 9600 baud passes 8 times the amount of data as a 1200 baud transmission in the same length of time. This means that 1000 characters could be sent at 9600 baud in the same amount of time as 125 characters sent at 1200 baud. This mode a little more work and modification. The high data rate causes the voice bandwidth of most transceivers to be exceeded. So in addition to a special modem, the modem needs to be connected directly into the IF of the receiver and into the modulator of the transmitter. This mode is for the interested experimenter now. The crew at the University of Surrey with assistance from some of the AMSAT-NA gurus are again pushing the technology in the finest traditions of amateur radio.

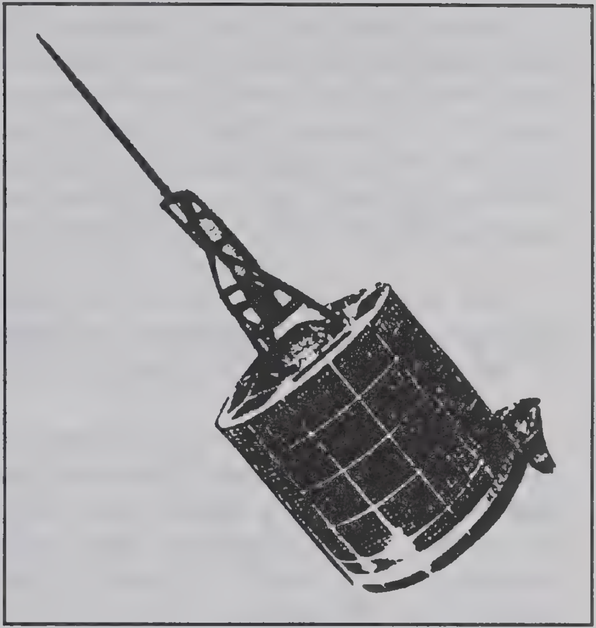
Future Telemetry Formats

The variety of telemetry transmission formats and the specialized equipment required to receive satellite telemetry keep many people from exploring satellite telemetry. Technology is currently available to provide a general purpose signal conversion unit. DSP (Digital Signal Processing) is becoming widely available and will allow one piece of hardware to be able to copy nearly all digital transmissions. This includes SSTV, FAX, RTTY, PSK with Manchester encoding, even 9600 baud AFSK will be possible. The price of these units may appear quite dear ($700 - $1000), but their versatility and the number of pieces of equipment they can replace make them very competitive. The DSP units are essentially under software control and will be able to demodulate nearly anything they are programmed to do. Currently AEA, L.L. Grace Communications Products, TAPR and DRSI are working on units and plug-in boards.

February 26, 1991

RS-10/11

Names: Radio Sputnik
Object #: 18129
International ID: 1987-054A
Launch: 23 June 1987
Period: 105 minutes
Increment: 26.3° west per orbit
Orbit: circular LEO
Altitude: avg 1000 km (621 miles)
Operating modes: CW, Voice, CW Robot
Telemetry: CW @ 20 wpm
Sponsoring country: USSR
Telemetry equipment needed:
  HF SSB receiver for 10 M, pre-amp helpful,
    antenna - 10 M dipole, beam
  VHF SSB receiver for 2 M, pre-amp helpful,
    antenna - 2 M J-pole, turnstile, or beam
  Software: CWTLM.BAS by WA4SXM



RS-10/11 are 2 separate amateur radio transponders aboard a Soviet COSMOS 1861 navigation satellite. The transponders can be used for voice or CW communication. Both of the transponders operate in one of five modes. Only one transponder is on at a time though.

There is no published mode schedule for the RS-10/11 transponders. When the satellite is due over your location, it is necessary to tune through all the beacon frequencies to determine which transponder is active and in which mode. Mode A appears to be the most common mode. The beacon frequencies are used for both ROBOT mode and telemetry. So no telemetry is available during ROBOT QSO's. I have found RS-11 to have a stronger signal than RS-10.

RS-10 Beacons	Mode	**RS-11 Beacons**	Mode
29.357 MHz	A,K,KA	29.407 MHz	A,K,KA
29.403 MHz	A,K,KA	29.453 MHz	A,K,KA
145.857 MHz	T,KT	145.907 MHz	T,KT
145.903 MHz	T,KT	145.953 MHz	T,KT

RS-10/11 telemetry

RS-10/11 telemetry is sent in CW about 20 WPM on the beacon frequency. The telemetry is composed of 16 status points and 16 analog measurements. Each telemetry frame is composed of the transponder identification (either RS10 or RS11), 16 groups of 4 alphanumeric characters, and the identifier as a terminator. These 16 groups contain an alpha part and a numeric part.

The alpha part of each group consists of the first 2 letters. These letter combinations describe a state of the device. The first letter is the alpha code that defines the state of a status point. The second letter is the the status point description code. Table 2.2 describes the standard alpha codes for RS-10/11 telemetry. Notice from Table 2.1 that for channels 1 - 8 that the first letter is either an I or an N and that the second letter is fixed. In channels/groups 9 - 16 the first letter is either an A or an M with the second letter fixed. Also note that the second letter sequence (S, R, D, G, U, W, K, O) repeats from the first group to the second. The fact that the second letter is fixed is a simplified method of error checking and also acts as a reference character. There is one known character in one known location in every group. This fact can aid stations in determining where in the frame sequence they are when they begin to copy the telemetry in the middle of a frame.

The numeric portion is a 2 digit decimal value that needs to be substituted into a calibration equation to determine the specific value of the measured quantity. See Table 2.1 for the status definition and analog calibration equations.

Recently a modified form of the RS-10/11 CW telemetry is has been heard in North America. When the ground command station (probably RS3A) accesses the satellite, the first letter of each telemetry group/channel has an extra dot or dash inserted. The selection of the dot or dash is determined by which uplink band the command station uses when issuing commands to the satellite. Figure 2.1 has examples of all three formats. The first example from 25 JAN 90 shows the standard format. The second example from 26 JAN 90 displays the modified format following a 2 meter uplink by the command station. The example from 29 JAN 90 shows the modified format following a 15 meter command station uplink.

If the 2 meter uplink frequency is used then a dash is inserted. The 15 meter uplink frequency causes a dot to be inserted.

Figure 2.1 Sample RS-10/11 CW telemetry acquired by WD5ZDP

```
24 JAN 90
           RS10 IS80 IR00 ND28 IG00 NU00 IW46 NK00 NO00
                AS34 AR34 AD37 AG33 MU00 MW00 MK46 AO89  RS10

26 JAN 90
           RS10 DS81 GR00 GD20 DG00 GU00 DW46 GK00 GO00
                KS32 KR24 KD35 KG34 OU00 OW00 OK00 KO89 RS10

29 JAN 90
           RS10 SS80 RR00 RD31 SG00 RU00 SW46 NK00 NO00
                US36 UR46 UD39 AG33 WU00 WW00 WK46 UO89 RS10

30 JAN 90
           RS10 IS80 NR00 ND24 IG00 NO00 IW46 NK00 NO00
                AS38 AR25 AD40 AG33 MU00 MW00 MK46 A089 RS10

02 FEB 90
           RS10 SS81 RR00 NS29 IG00 NU00 SW46 ND00 RO00
                US34 UR27 MD37 UG35 MU00 MW00 MK46 AO89 RS10
```

Looking at Table 2.1 notice that the standard first alpha code is an I or an N for groups 1 - 8 and an A or an M for groups 9 - 16. If a 2 meter command uplink was used, this would change the first alpha character to a D and a G for groups 1 - 8, and a K and an O for groups 9 - 16. If the 15 meter uplink was used by the command station, the first alpha character would become S or R, and U or W. If the CW you copy doesn't fit the standard format, use the data in Table 2.3 to convert the received first characters back to the standard first alpha character, then decode the data in the conventional fashion. Note that these conversions are only for the first alpha character, the other three characters in each group should fit the standard format. Table 2.4 lists all combinations of the alpha codes and their definitions.

Figure 2.2 Sample decoding of standard RS-10/11 telemetry using Table 2.1

RS10 IS80 NR25 ID19 NG45 NU45 IW00 IK00 IO00
AS35 AR23 AD38 MG31 AU00 AW46 AK46 AO89 RS10

Group 1 IS80	I = 90 minutes S = telemetry sampling period V = 80/4 = 20 volts average supply voltage over the 90 minute sampling period
Group 2 NR25	N = 0 dB RX attenuation add to group 3 W = 25/10 = 2.5 watts 2 M xmit power
Group 3 ID19	I = 10 dB + 0 dB from group 2 = 10 dB receive attenuation W = 19/10 = 1.9 watts 10 M xmit power
Group 4 NG45	N = On, 15 M receiver is on V = 45/5 = 9 volts for 15 M AGC voltage
Group 5 NU45	N = On, 2 M receiver is on V = 45/5 = 9 volts for 2 M AGC voltage
Group 6 IW00	I = Off, Command station channel is off V = 0/5 = 0 volts for command station AGC voltage
Group 7 IK00	I = 1000 mW, 10 M service command 0 = Off for the service command
Group 8 IO00	I = 1000 mW, 2 M service command 0 = Off for the service command
Group 9 AS35	A = Off, Status of 1st memory board T = 35 - 10 = 25 deg C for 10 M XMTR temperature
Group 10 AR23	A = OFF, Status of 2nd memory board T = 23 - 10 = 13 deg C for 2 M XMTR temperature
Group 11 AD38	A = Open, Memory loading channel is open T = 38 - 10 = 28 deg C for 20 V power supply temperature
Group 12 MG31	A = Open, Code Store memory status is open T = 31 - 10 = 21 deg C for 9 V power supply temperature
Group 13 AU00	A = 10 M, Memory dump is via 10 M V = 0/5 = 0 volts for control of backup 9V power supply
Group 14 AW46	A = 10 dB attenuation of 15 Robot receiver V = 46/5 = 9.2 volts in IF of 15 M Robot receiver
Group 15 AK46	A = 10 dB attenuation of 2 Robot receiver V = 46/5 = 9.2 volts in IF of 2 M Robot receiver
Group 16 AO89	A = 1000 mW for 2 M Command channel output 89 = # of Robot QSO's is > 33 and < 128

Table 2.1 RS-10/11 calibration and status equations

Code	alpha code meaning	formula	parameter description
1 I/N	S = Telemetry sampling period	V = n/4 volts	supply voltage over sample time
2 I/N	R = RX attenuation (2 + 3)	W = n/10 watts	2 M XMIT output power
3 I/N	D = RX attenuation (2 + 3)	W = n/10 watts	10 M XMIT output power
4 I/N	G = 15 M receive status	V = n/5 volts	15 M RX AGC voltage
5 I/N	U = 2 M receive status	V = n/5 volts	2 M RX AGC voltage
6 I/N	W = Service channel status	V = n/5 volts	Service channel AGV voltage
7 I/N	K = 10 M command mode	0 = off	Command mode parameter
8 I/N	O = 2 M command mode	0 = off	Command mode parameter
9 A/M	S = Status of 1st memory board	T = n - 10 C	10 M XMTR temperature
10 A/M	R = Status of 2nd memory board	T = n - 10 C	2 M XMTR temperature
11 A/M	D = Memory loading channel	T = n - 10 C	20 V power supply temperature
12 A/M	G = Code Store memory status	T = n - 10 C	9 V power supply temperature
13 A/M	U = Memory dump via channel	V = n/5 volts	Control of 9V backup power supply
14 A/M	W = 15 M Robot RX attenuation	V = n/5 volts	IF voltage of 15 M Robot receiver
15 A/M	K = 2 M Robot RX attenuation	V = n/5 volts	IF voltage of 2 M Robot receiver
16 A/M	O = Command channel 2 M output	0 = 0-32 QSO's 80 - 99 = 33 - 128 QSO's	Robot QSO counter

Table 2.2 Standard first alpha code status of RS-10/11 CW telemetry

1 I = 90 minutes
N = 10 minutes

2 I = 20dB attenuator
N = 0dB attenuator

3 I = 10dB attenuator
N = 0dB attenuator

4 I = Off
N = On

5 I = Off
N = On

6 I = Off
N = On

7 I = 1000 mW
N = 300 mW

8 I = 1000 mW
N = 300 mW

9 A = Off
M = On

10 A = Off
M = On

11 A = Open
M = Closed

12 A = Open
M = Closed

13 A = 10 M
M = 2 M

14 A = 10 dB
M = 0 dB

15 A = 10 dB
M = 0 dB

16 A = 1000 mW
M = 300 mW

Table 2.3 RS-10/11 first alpha character conversion table

Standard	2M uplink	15M uplink
I	D	S
N	G	R
A	K	U
M	R	W

Table 2.4 Complete RS-10/11 alpha code decoding table

Channel
1 IS = 90 minute sampling period
DS = 90 minute sampling period
SS = 90 minute sampling period

NS = 10 minute sampling period
GS = 10 minute sampling period
RS = 10 minute sampling period

2 IR = 20 dB receiver attenuator (add to group 3 value)
DR = 20 dB receiver attenuator (add to group 3 value)
SR = 20 dB receiver attenuator (add to group 3 value)

NR = 00 dB receiver attenuator (add to group 3 value)
GR = 00 dB receiver attenuator (add to group 3 value)
RR = 00 dB receiver attenuator (add to group 3 value)

3 ID = 10 dB receiver attenuator (add to group 2 value)
DD = 10 dB receiver attenuator (add to group 2 value)
SD = 10 dB receiver attenuator (add to group 2 value)

ND = 00 dB receiver attenuator (add to group 2 value)
GD = 00 dB receiver attenuator (add to group 2 value)
RD = 00 dB receiver attenuator (add to group 2 value)

4 IG = OFF, 15 meter receiver status
DG = OFF, 15 meter receiver status
SG = OFF, 15 meter receiver status

NG = ON, 15 meter receiver status
GG = ON, 15 meter receiver status
RG = ON, 15 meter receiver status

5 IU = OFF, 2 meter receiver status
DU = OFF, 2 meter receiver status
SU = OFF, 2 meter receiver status

NU = ON, 2 meter receiver status
GU = ON, 2 meter receiver status
SU = ON, 2 meter receiver status

6 IW = OFF, service channel status
DW = OFF, service channel status
SW = OFF, service channel status

NW = ON, service channel status
GW = ON, service channel status
RW = ON, service channel status

7 IK = 1000 mW for 10 meter command mode
DK = 1000 mW for 10 meter command mode
SK = 1000 mW for 10 meter command mode

NK = 300 mW for 10 meter command mode
GK = 300 mW for 10 meter command mode
RK = 300 mW for 10 meter command mode

8 IO = 1000 mW for 2 meter command mode
DO = 1000 mW for 2 meter command mode
SO = 1000 mW for 2 meter command mode

NO = 300 mW for 2 meter command mode
GO = 300 mW for 2 meter command mode
RO = 300 mW for 2 meter command mode

Table 2.4 continued Complete RS-10/11 alpha code decoding table

Channel
9 AS = OFF, status of 1st memory board
KS = OFF, status of 1st memory board
US = OFF, status of 1st memory board

MS = ON, status of 1st memory board
RS = ON, status of 1st memory board
WS = ON, status of 1st memory board

10 AR = OFF, status of 2nd memory board
KR = OFF, status of 2nd memory board
UR = OFF, status of 2nd memory board

MR = ON, status of 2nd memory board
RR = ON, status of 2nd memory board
WR = ON, status of 2nd memory board

11 AD = OFF, memory loading channel
KD = OFF, memory loading channel
UD = OFF, memory loading channel

MD = ON, memory loading channel
RD = ON, memory loading channel
WD = ON, memory loading channel

12 AG = OFF, Code store memory status
KG = OFF, Code store memory status
UG = OFF, Code store memory status

MG = ON, Code store memory status
RG = ON, Code store memory status
WG = ON, Code store memory status

13 AU = Memory output to 10 meters
KU = Memory output to 10 meters
UU = Memory output to 10 meters

MU = Memory output to 2 meters
RU = Memory output to 2 meters
WU = Memory output to 2 meters

14 AW = 15 meter ROBOT receiver attenuation, 10 dB
KW = 15 meter ROBOT receiver attenuation, 10 dB
UW = 15 meter ROBOT receiver attenuation, 10 dB

MW = 15 meter ROBOT receiver attenuation, 00 dB
RW = 15 meter ROBOT receiver attenuation, 00 dB
WW = 15 meter ROBOT receiver attenuation, 00 dB

15 AK = 2 meter ROBOT receiver attenuation, 10 dB
KK = 2 meter ROBOT receiver attenuation, 10 dB
UK = 2 meter ROBOT receiver attenuation, 10 dB

MK = 2 meter ROBOT receiver attenuation, 00 dB
RK = 2 meter ROBOT receiver attenuation, 00 dB
WK = 2 meter ROBOT receiver attenuation, 00 dB

16 AO = 1000 mW for 2 meter command mode
KO = 1000 mW for 2 meter command mode
UO = 1000 mW for 2 meter command mode

MO = 300 mW for 2 meter command mode
RO = 300 mW for 2 meter command mode
WO = 300 mW for 2 meter command mode

Analyzing RS-10/11 telemetry

Here are some of the things we can glean from the RS-10/11 telemetry data.

1) Which mode is the satellite is in?
2) How much power is the transmitter using?
3) How much attenuation does the receiver need?
4) What is the temperature of the transmitter?
5) What is the temperature of the power supply?
6) How many QSO's has the ROBOT had?

Studying the data over a number of passes we can begin to correlate things like how does the current drain and receiver attenuation change with different numbers of users. What system changes occur when the satellite goes from illumination to eclipse?

Let's look at Mode determination. Group 4 tells us whether the 15 meter receiver is on or not. Group 5 tells us the status of the 2 meter receiver.

An I, D, or S means that the receiver is OFF, an N, G, or R means that it is ON.

So from the examples in Figure 2.1, we see that the 15M receiver was OFF during the sample times, and that the 2M receiver was ON during all the samples. This tells us that the spacecraft was in Mode A, not Mode KA.

The transponder transmit power is found in group 3 analog data. The data in Figure 2.1 tells us that the 10M transmitter was using power levels of 2.8, 2.0, 3.1, 2.4 and 2.9 watts

The ROBOT QSO counter probably doesn't function as intended. A total count of 00 is recorded until 32 QSO's have taken place made. The count then jumps to 80 on the 33rd QSO. Counts between 80 - 99 occur between actual QSO's 33 - 128. The count just puts you in the ball park.

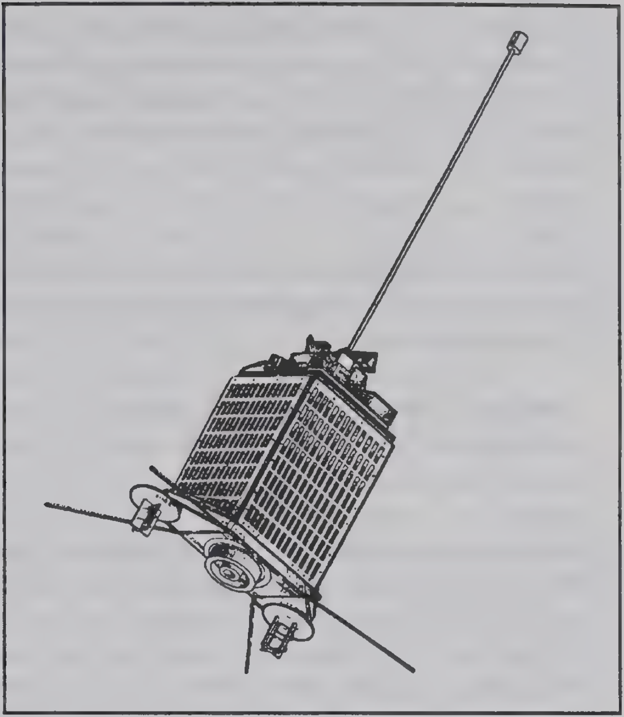
February 15, 1991

UO-11

Names: UoSAT-2, UoSAT-B
Object #: 14781
International ID: 1984-021B
Launch: 1 March 1984
Period: 99 minutes
Increment: 24.6° west per orbit
Orbit: circular LEO
Altitude: avg 680 km (423 miles)
Operating modes: Telemetry, Voice, command station packet store and forward (mailbox)
Sponsor: University of Surrey, England

Telemetry: 1200 bps, FM AFSK
145.825 MHz
435.025 MHz

Telemetry equipment needed:
2 M, 70 cm FM receiver, Bell type 202 AFSK modem (G3RUH board or other ASCII decoder), pre-amplifier
Antenna: 2 M, 70 cm, 13 cm LHCP pointable beam



Software: ASCII: by N5AHD from AMSAT-NA, by G1WTW from AMSAT-UK
Packetized: DTLM by K8KA from AMSAT-UK

The UoSat-2 (UO-11) satellite was designed and constructed by the UoSat Spacecraft Engineering Research Unit of the Department of Electronic and Electrical Engineering, University of Surrey, England. It is currently the 'grand dame' of amateur satellites. This satellite was part of a project to develop scientific experimentation and space education. The department utilizes practical projects in the curriculum. This provides invaluable experience in a "real world" environment . The satellite is still functioning quite well after 6 years aloft, which says much about the quality of the project design, leadership and workmanship. Telemetry is sent from four experiments aboard as well as satellite operational data.

There are 4 experiments aboard UO-11:
1) Digital Communication Experiment (DCE);
2) Space Dust experiment;
3) CCD experiment; and
4) Digitalker experiment.

Due to the educational/experimental nature of the satellite a number of different formats are used to send the data back to earth. The University of Surrey has produced a number of publications concerning the experiments and the data formats (see Appendix F). I will mainly examine the operational and WOD (Whole Orbit Data).

Digital Communication Experiment:

The DCE is an experimental store and forward mailbox using digital communication. Command stations acting as gateways from terrestrial packet networks can upload messages to the satellite, have the satellite store the messages and another command station may download the messages and complete the transfer. This is proven to be a good method of transferring packet data globally. We need to remember that this has been in place since 1984.

Cosmic Dust Experiment: This experiment was built by the students at the University of Kent, England. It measures the impact of cosmic dust particles and calculates the momentum of the particles.

Charged Coupled Device Camera (CCD): Takes pictures of the earth from space at a resolution of 384 x 256 pixels with 128 grey levels. This has the potential to produce quite a sharp picture.

Digitalker experiment: The Digitalker voice chip produces very clear digital voice signals from a fixed vocabulary. This experiment can articulate the telemetry data or message data. In 1988 UO-11 was used by the Skitrek team, a joint Soviet/Canadian team traversed the North Pole on skies, for location information. The skiers carried 2M handitalkies and emergency locator transmitters (ELT). SARSAT search and rescue satellites were used to locate the skiers. This information was relayed to the University of Surrey and uploaded to UO-11. The digitalker experiment then vocally relayed the skiers position to then on 145.825 MHz. School children and hams all over the world were able to track the skiers progress.

Receiving the telemetry

A FM receiver connected to a pointable antenna with a preamp is necessary to receive data from horizon to horizon. It is necessary to maintain a strong signal throughout the pass to receive error-free data. The fact that you can hear the signal well does not necessarily mean that the digital data can be extracted correctly. Noise and signal fades cause invalide interpretation of the bits. Strive for the best receive station you can assemble.

Demodulating the telemetry

After acquiring the telemetry signal it is necessary to demodulate it. Most of the UO-11 transmissions are a 1200 bps AFSK modulated signal. Tones shift between 1200 and 2400 Hz and can be demodulated into bit patterns easily readable through the serial port of a computer/terminal. The modulation scheme for UO-11 is a 1200 Hz tone for a 0 bit(space) and a 2400 Hz tone for a 1 bit(mark). This tone to bit conversion is opposite from that of the Bell 202 standard. I have used three demodulators to convert the UO-11 data: (1) the G3RUH demodulator, (2) a modified AEA PK-232 unit, and (3) a very simple 3 IC unit.

A description and schematic of the G3RUH unit has appeared in articles in "Radio and Wireless World" and in "Ham Radio" magazines. The printed circuit board is available from AMSAT-UK. The operator must order parts and be capable of building the unit built from the schematic. Then a fair amount of test equipment is needed to align the device. Once completed. This unit will perform quite well when given a low noise signal. I would not recommend this approach to an occasional builder. I have included assembly and alignment hints in Appendix H.

To use the AEA PK-232 unit for UO-11 telemetry a simple modification is necessary. If you can read a schematic and solder well, you should have no trouble. This modification is referenced in the Bibliography. The modification is to insert a toggle switch so that the tone to bit conversion can be inverted in the PK-232. After modification the unit works about as well as the G3RUH demodulator.

The 3-chip demodulator circuit is found in the August 1984 QST magazine and the ARRL Satellite Anthology. It is fairly easy to build and will work for 4 - 5 minutes during the strongest part of the orbit. A Bell type 202 modem, modified to invert the tone to bit conversion, may also be used. These modems can be found as surplus items at hamfests. DO NOT USE BELL type 212, the most common 1200 baud modem for personal computers. The 212 type uses a phase shift modulation instead of the audio shift modulation.

UoSat-2 serial data formats

Initially the telemetry, WOD, and bulletins were sent as straight 7-bit ASCII characters using a serial format of 1200 bps, 7 data bits, EVEN parity, and 2 stop bits. This format is still in use today. The CCD experiment and the DCE both used hexadecimal formats. But in the latter half of the 1980's the University of Surrey team wanted to take advantage of the availability of computers to increase the amount of data transferred. A new operating system was written that would regularlly switch tasks and send the same data in a more efficient format. The experimental, diary and operational data are now sent as hexadecimal values at 1200 bps using 8 data bits, NO parity, and 1 STOP bit. Today both the 7-bit and the 8-bit serial formats are regularly transmitted. The biggest problem is that terminal programs are unable to decode both formats simultaneously. It is up to the operator to select which of these transmission he wishes to receive, and set the corresponding serial parameters accordingly. The demodulator simply converts the tones into bit patterns, it is up to the terminal program to interpret the bit patterns. Many of the 7-bit ASCII characters can be recognized using the 8-bit terminal parameters, but the 8-bit data causes the terminal to behave erratically. The 7-bit, ASCII data is slow, not very efficient, readable, and most programs can store the data. Every terminal program I have used has had no problem in storing the 7-bit ASCII data. Since both 7-bit and 8-bit data are transmitted by UO-11, when the terminal program is configured for 7-bit operation the received 8-bit data is garbage. So the terminal program will also store the garbage data. It is up to the operator to go into the file with a text editor and strip out the usable 7-bit data. The 8-bit, hexadecimal data is fast, efficient, not readable and difficult for terminal programs to store correctly. Many of the terminal programs do not store all the control characters. Even though you may see graphic representations of the control characters on the terminal screen, these characters are not stored to the file. Make sure that the terminal program you are using will store all control characters to a file. The Procomm terminal program will store all but the <NULL> 00h character in the ASCII download mode, but even fewer of the control characters in the Log File function. You have probably noticed that displaying the 8-bit data as it is received causes erratic behavior of the terminal screen. The reason for this is that the hexadecimal characters 00h-1Fh are interpreted as ASCII control characters. These characters cause specific actions (like carriage returns, form feeds and cursor movements) by terminal programs, that appear as erratic behavior. After studying the ASCII examples, listening to the audio, and watching the ASCII data display on the screen, you will be able to identify the ASCII data type coming down by the rhythm.

One method of decoding both data formats is to record the pass on audio tape. Then use the recorded audio as input to the demodulator, configure the terminal for the 8-bit serial format, decode the data, rewind the tape, reconfigure the terminal for the 7-bit serial format, an decode that data. The operating system for the UO-11 spacecraft switches tasks or operations at set intervals. It is not unusual for data to be shut off midstream, and another type of data transmission to begin.

UO-11 ASCII Telemetry

A typical data frame is composed of the ASCII <RS> character (1Eh) - used as an initialization/sync character, the satellite identifier, date/day/time group, and then the data. The data portion of the frame contains 70 channels of information (68 of these are defined). These are sent in 7 lines of 10 channels each. 59 of these channels contain analog measurements, with the remaining 11 channels reporting 96 status points. Figure 3.1 is an actual UO-11 telemetry frame. The satellite identifier is obvious, but the date/time group may be a bit cryptic. It is in YYMMDDWHHMMSS format. (UTC year, month, day), day of the week (Sunday = 0), HHMMSS (UTC hours, minutes, seconds). Each channel is composed of 5 digits. The first two are the decimal channel number. Three decimal data values follow. The last character is the hex checksum for the channel. It takes more space and time to transmit a checksum with each channel, but an entire frame is not lost if one channel is incorrect. The data values are computed using the UO-11 equations in Table 3.1. Updates to the calibration equations are found on the weekly bulletins and are available from the University of Surrey, UoSAT Spacecraft Engineering research Unit.

Figure 3.1 UO-11 sample ASCII telemetry data

```
UOSAT-2             9008175013353

00522501450002222003455704051005038E06024007051308045909040D
10522411329812000313055214070215508916188617605518647C195863
205227212221226600230001240017250007260958276267286387295169
30522631035432285E33574634007035220636278837433038466F394970
40650741120642642643061044161645000146000247484B48500949470E
50459D51110452623053628A54651355000056000357493C584876594899
6082E2615FC1625F4A633341644402651E0C66020267700668000E69000F
**!!!c**!!!c**!!!c**!!!c**!!!c**!!!c**!!!c**!!!c**!!!c**!!!c
** channel    !!! data        c checksum
```

Decoding UO-11 ASCII telemetry

Following are examples of decoding telemety by hand and the output from available UoSAT-2 decoding software. To manually decode the analog data select a channel, get the 3 decimal data values for that channel and substitute in the appropriate calibration equation. The calibration equations are found in Table 3.1. The status portion is decoded by taking the hexadecimal values, breaking them into binary and then determining the state of each of the status points by its 1 or 0 value. The checksum is computed for each channel by XORing (eXclusive ORing) each nibble (4 bits) of all 6 characters per channel. A zero result means that the data was received correctly, non-zero result means the data was corrupted. Appendix C has explanations of differnt number bases, XOR, conversion examples and a conversion table.

Figure 3.2 Example of decoding UO-11 telemetry by hand using data from Figure 3.1

```
The UO-11 data in Figure 3.1 was received 9008175013353, this is the compact
way of encoding  1990 AUG 17 FRI 01:33.53 UTC.

channel 00  data 522  checksum 5
Do the checksum first to see whether the data is valid or not.  First break the
data into 4 bit groups, then XOR the first with the second.  Then take the
result and XOR with the next until through.

    0           0           5             2             2             5
0000 0000   0000 0000   0000 0101     0000 0010     0000 0010     0000 0101
   XOR -> 0    XOR -> 0    XOR -> 0101    XOR -> 0111   XOR -> 0101   XOR ->0000
the data is valid, continue.

solar array current -Y face ->  I = 1.9( 516 - 522 ) -> -11.4 mA

channel 01  data 450  checksum 0
Navigational magnet X axis -> H = (0.1485 * 450) - 68 -> -1.175 uT

channel 18  data 674  checksum C
Facet temperature of the +Y face -> T = (480 - 674) / 5 -> -33.4 deg C

channel 33  data 574  checksum 6
1802 based +10v computer current -> I = 0.21 * 574 -> 120.54 mA

channel 60  data 82E  checksum 2
binary value of 83E ->  MSB 1000 0010 1110 LSB

145 MHz general beacon power             1 -> On
435 MHz Engineering beacon power         0 -> Off
2401 MHz Engineering beacon power        0 -> Off
Telemetry channel mode select            0 -> Run

Telemetry channel dwell address load     0 -> Off
Telemetry channel dwell address source   0 -> Gnd
Primary spacecraft computer power        1 -> On
Primary spacecraft computer error cnt    0 -> bit 1 of 3

Primary spacecraft computer error cnt    1 -> bit 2 of 3
Primary spacecraft computer bootstrap    1 -> PROM
Primary spacecraft computer error cnt    1 -> bit 3 of 3, (011 or 3 errors)
Primary spacecraft computer bootstrap    0 -> A program
```

Choosing a few channels and decoding them by hand is a nice exercise, but hardly a very practical approach. With all the telemetry information available from UO-11 it would be very time consuming to calibrate the analog values and determine the status of 96 points. This is exactly the type of operation a computer was designed for, repetitious calculations. I know of two programs available for the IBM PC class of machines to decode the telemetry from UO-11. One program processes the data after it has been recorded to disk and the other program does real-time decoding of the telemetry. Both are extremely useful, and serve two approaches to analyzing telemetry data. One approach is to mill over the data, looking for patterns or relationships between events. The other approach is to do a quick survey of the data to look for abnormalities. Both programs only work on the telemetry data frame, not the WOD.

The program by Craig Underwood, G1WTW of AMSAT-UK decodes and displays the telemetry values on the screen as the data is received. This program is called TLM2. Only the analog portion of the data is decoded, no status points. There are no units associated with the values, but they can be found in Table 3.1. The program displays the current computer clock time as GMT, instead of the time sent with the telemetry frame. It is important to have your note the actual UTC time if your computer clock is not set to UTC. You can do a print screen function to get a hardcopy of the data. After you become familiar with the baseline values for UO-11 telemetry, this program provides a quick display of the current data to determine whether all systems are functioning correctly. While no telemetry frames are being sent, nothing appears on the screen, but the program is running. The data is not stored to disk for later analysis, nor can the program read data from a file. Figure 3.3 displays the G1WTW screen using the data from Figure 3.1. Data source was an audio tape of the received signal. The last update time shown was the local time not the actual received data time. The data was received Fri Aug 17,1990 01:33:53.

Figure 3.3 Screen display of UO-11 analog telemetry data decoded by the G1WTW program.

```
UoSAT-OSCAR-11 (UoSAT-2) SATELLITE : REAL-TIME ENGINEERING ANALOGUE TELEMETRY

Last Update:    Saturday   18 August 1990     01:12:23 GMT

Sol Array Curr +Y   -11.4  DCE GMEM Current      31.7  145MHz Tx Pwr O/P   275.0
Sol Array Curr -Y   -11.4  Batt Volts +14V      130.8  145MHz Tx Current    61.2
Sol Array Curr +X   -11.4  Cell Volts (MUX)       0.0  145MHz Tx Temp        9.4
Sol Array Curr -X   -11.4  Sol Arr Volt +30V     13.4  435MHz Tx Pwr O/P  -200.0
Batt Chg/Dis Curr -475.2  PCM Volts +10V         9.9  435MHz Tx Current     0.0
+14V Line Current  550.0  PCM Volts +5V          5.3  435MHz Tx Temp        0.8
+10V Line Current  215.3  PCM Volts -10V        10.3  2.4GHz Tx Pwr O/P     5.2
+5V Line Current   116.4  Facet Temp +Y        -33.4  2.4GHz Tx Current     0.0
-10V Line Current   16.8  Facet Temp -Y        -31.6  2.4GHz Tx Temp       -1.4
1802 Current +10V  120.5  Facet Temp +X        -25.0  435MHz Tx VCO Ctl     0.3
DIGITALK Curr +5V    0.9  Facet Temp -X        -29.2  Nav Mag X Axis       -1.2
TLM Current +10V    13.0  Facet Temp +Z        -21.2  Nav Mag Y Axis       -0.4
Cmmd Rx Current    148.1  Facet Temp -Z         -7.2  Nav Mag Z Axis      -35.5
DSR Current +5V     12.8  Cmmd Dec Temp +Y       2.8  Sun Sensor #1         0.0
PW Logic Curr +5V    0.0  BCR Temp -Y            2.0  Sun Sensor #2         0.0
PW G-M  Curr +14V    0.2  Telemetry Temp +X     -3.4  Sun Sensor #3         0.0
PW E-Sp Curr +10V    0.0  PW Temp -X            -4.0  Sun Sensor #4         0.0
PW E-Sp Curr -10V    8.8  CCD Imager Temp       -1.8  Sun Sensor #5         0.0
DCE RAMUNIT Curr    -0.1  Battery Temp          -2.6  Sun Sensor #6         0.0
DCE CPU Current    160.5 Nav Mag Wing Temp      0.3  Horizon Sensor        0.0
 V 1.0 (c) 1990 AMSAT-UK                              Craig I. Underwood G1WTW
```

==

The program by Robert Diersing, N5AHD does post-processing of the captured data. In addition, Robert provides a data capture program and an editing program. The capture program is used to store the ASCII data to disk. The editing program is used to separate the telemetry frames from the other data. Figure 3.4 is an example of the data from Figure 3.1 decoded using the N5AHD program to decode it. The first page of the N5AHD program output is the status points for the satellite. You are prompted as to whether you wish the status page decoded once per decode session or for every frame received. There are many decoding examples and a great deal of useful information about UO-11 telemetry supplied as a document file with the N5AHD program. The information in the document is as useful as the decoding program itself. The N5AHD program decodes both the analog and status values.

Figure 3.4 N5AHD UO-11 decoding software output using the data from Figure 3.1

```
--- UoSAT-OSCAR-11 --- Spacecraft Systems Status --- 08/17/90 --- 01:33:53 ---
-------------------------------------------------------------------------------
145 MHz Gen Beacon Pwr       1=On      435 MHz Eng Beacon Pwr        0=Off
2401 MHz Eng Beacon Pwr      0=Off     Tlm Chan Mode Select          0=Run
Tlm Chan Dwell Addr Load     0=Off     Tlm Chan Dwell Addr Source    0=Gnd
Pri S/C Computer Pwr         1=On      Pri S/C Comp Err Cnt          0=Bit-1
Pri S/C Comp Err Cnt         1=Bit-2   Pri S/C Comp Bootstrap        1=UART
Pri S/C Comp Err Cnt         1=Bit-3   Pri S/C Comp Bootstrap        0=A
Grav Grad Boom Deploy Pyro   0=Safe    Grav Grad Boom Deploy Pyro    1=Fire
Grav Grad Boom Deployment    0=Safe    Grav Grad Boom Deployment     1=Dply
Grav Grad Boom Deployment    1=Ret     Attitude Ctrl Magnetorquer    1=Arm
Attitude Ctrl Mag -X         1=Off     Attitude Ctrl Mag -Y          1=Off
Attitude Ctrl Mag -Z         1=Off     Attitude Ctrl Magnetorquer    1=Fwd
435 MHz PSK Mode             0=NRZI    2401 MHz PSK Mode             0=NRZI
Attitude Ctrl Magnetorquer   0=High    Digitalker Power              1=On
CCD Power                    0=Off     CCD Integration Pd            1=Bit-0
CCD Integration Pd           1=Bit-1   CCD Video Amp Gain            1=Bit-0
CCD Video Amp Gain           1=Bit-1   DSR Power                     1=On
DSR Mode                     0=Read    DSR Mode                      1=Rst
Rad Det Geiger-A EHT Pwr     0=Off     Rad Det Geiger-B EHT Pwr      0=Off
Rad Det Geiger-C EHT Pwr     0=Off     Electron Spect Sensor EHT Pwr 0=Off
DCE Power                    1=On      DCE                           1=Rst
DCE PROM Select              0=A       DCE CPU Clock Rate Select     0=0.9
Nav Magnetorquer Power       1=On      Space Dust Expt Pwr           1=On
Space Dust Level Select      0=Bit-0   BCR Status                    1=1
435 MHz Downlink Mod Sel     0=AFSK    2401 MHz Downlink Mod Sel     0=AFSK
1802 Serial Cmd              0=Dis     DCE Serial Cmd                1=Enab
                             0=0                                     0=0
                             0=0       Command Watchdog Enable       1=1
Command Watchdog Reset       0=0       145 MHz Downlink Data Sel     0=0
145 MHz Downlink Data Sel    0=0       145 MHz Downlink Data Sel     0=0
145 MHz Downlink Data Sel    0=0       145 MHz Downlink Data Sel     0=0
145 MHz Downlink Data Sel    0=0       145 MHz Data Rate             0=0
145 MHz Data Rate            0=0       435 MHz Data Rate             1=1
435 MHz Data Rate            1=1       435 MHz Data Rate             1=1
Particle/Wavecounter Ctrl    1=Reset   Downlink Lockout              0=Enab
                             0=0                                     0=0
                             0=0                                     0=0
P/W Chan Plate Control       0=Bit-0   P/W Chan Plate Control        0=Bit-1
P/W Chan Plate Control       0=Bit-2   Space Dust                    0=0
Space Dust                   0=0       Space Dust                    0=0
Space Dust                   1=1       Space Dust                    0=0
Space Dust                   0=0       Space Dust                    0=0
Space Dust                   0=0       DSR Write Cycle Complete      0=0
1802 CWO Output              0=0       1802 TLM Port (MSB)           1=1
1802 TLM Port                1=1       1802 TLM Port                 1=1
1802 TLM Port                0=0       1802 TLM Port                 0=0
1802 TLM Port                0=0       1802 TLM Port                 0=0
1802 TLM Port                0=0       1802 TLM Port                 0=0
1802 TLM Port                0=0       1802 TLM Port (LSB)           0=0
```

Figure 3.4 continued   N5AHD UO-11 decoding software output

```
--- UoSAT-OSCAR-11 --- Spacecraft Telemetry Data --- 08/17/90 --- 01:33:53 ---
------------------------------------------------------------------------------
Channel        Description                       Raw Data   Eng Data   Units
   0     Solar Array Current -Y                     522     -11.400   mA
   1     Nav Magnetometer X Axis                    450      -1.175   uT
   2     Nav Magnetometer Z Axis                    222     -35.489   uT
   3     Nav Magnetometer Y Axis                    455      -0.431   uT
   4     Sun Sensor No. 1                            51      +0.000
   5     Sun Sensor No. 2                            38      +0.000
   6     Sun Sensor No. 3                            24      +0.000
   7     Sun Sensor No. 4                            51      +0.000
   8     Sun Sensor No. 5                            45      +0.000
   9     Sun Sensor No. 6                            40      +0.000
  10     Solar Array Current +Y                     522     -11.400   mA
  11     Nav Magnetometer Temp                      329      +0.290   Degrees C
  12     Horizon Sensor                               0      +0.000
  13     Spare                                       55      +0.000
  14     DCE RAMUNIT Current                         70      -0.060   mA
  15     DCE CPU Current                            508    +160.450   mA
  16     DCE GMEM Current                           188     +31.762   mA
  17     Facet Temperature +X                       605     -25.000   Degrees C
  18     Facet Temperature +Y                       647     -33.400   Degrees C
  19     Facet Temperature +Z                       586     -21.200   Degrees C
  20     Solar Array Current -X                     522     -11.400   mA
  21     +10 Volt Line Current                      222    +215.340   mA
  22     PCM Voltage +10V                           660      +9.900   Volts
  23     P/W Logic Current (+5V)                      0      +0.000   mA
  24     P/W Geiger Current (+14V)                    1      +0.210   mA
  25     P/W Elec sp.curr (+10V)                      0      +0.000   mA
  26     P/W Elec sp.curr (-10V)                     95      +8.835   mA
  27     Facet Temperature -X                       626     -29.200   Degrees C
  28     Facet Temperature -Y                       638     -31.600   Degrees C
  29     Facet Temperature -Z                       516      -7.200   Degrees C
  30     Solar Array Current +X                     522     -11.400   mA
  31     -10 Volt Line Current                       35     +16.800   mA
  32     PCM Voltage -10V                           285     +10.260   Volts
  33     1802 Computer Current (+10V                574    +120.540   mA
  34     Digitalker Current (+5V)                     7      +0.910   mA
  35     145 MHz Beacon Power Output                220    +275.000   mW
  36     145 MHz Beacon Current                     278     +61.160   mA
  37     145 MHz Beacon Temperature                 433      +9.400   Degrees C
  38     Command Decoder Temperature (+Y)           466      +2.800   Degrees C
  39     Telemetry System Temperature (+X)          497      -3.400   Degrees C
  40     Solar Array Voltage (+30V)                 650     +13.400   Volts
  41     +5 Volt Line Current                       120    +116.400   mA
  42     PCM Voltage +5V                            642      +5.393   Volts
  43     DSR Current (+5V)                           61     +12.810   mA
  44     Command Receiver Current                   161    +148.120   mA
  45     435 MHz Beacon Power Output                  0    -200.000   mW
  46     435 MHz Beacon Current                       0      +0.000   mA
  47     435 MHz Beacon Temperature                 484      -0.800   Degrees C
  48     P/W Temperature (-X)                       500      -4.000   Degrees C
  49     BCR Temperature (-Y)                       470      +2.000   Degrees C
  50     Battery Charge/Discharge Current           459    -475.200   mA
  51     +14 Volt Line Current                      110    +550.000   mA
  52     Battery Voltage (+14V)                     623    +130.830   Volts
  53     Battery Cell Voltages (MUX)                628      +0.000
  54     Telemetry System Current                   651     +13.020   mA
  55     2401 MHz Beacon Power Output                 0      +5.208   mW
  56     2401 MHz Beacon Current                      0      +0.000   mA
  57     Battery Temperature                        493      -2.600   Degrees C
  58     2401 MHz Beacon Temperature                487      -1.400   Degrees C
  59     CCD Imager Temperature                     489      -1.800   Degrees C
```

UO-11 Bulletin data

ASCII bulletins concerning the spacecraft and amateur satellite operations in general are uploaded weekly. Figure 3.5 is an example of a UO-11 bulletin.

Figure 3.5 UoSAT-2 bulletin

```
* UOSAT-2 OBC STATUS INFORMATION *

DIARY OPERATING SYSTEM V3.1 SMH MLJM MSH

 Today's date is 17 /8 /90  (Friday)
 Time is 1 :33 :45 UTC
 Auto Mode is selected
 Spin Period is - 226
 Z Mag firings  = 0
 + SPIN firings = 31
 - SPIN firings = 22
 SEU count      = 705
 RAM WASH pointer at 170A
 WOD commenced 17 /8 /90 at 0 :0 :8
 with channels 0 ,10 ,20 ,30 ,
 Last cmnd was 109 to 0 , 0
 Attitude control initiated, mode 1
 Data collection in progress
 Digitalker active

         **** UoSAT-OSCAR-11 BULLETIN - 218      07 August 1990   ****

                          UoSAT MISSION CONTROL CENTRE
          University of Surrey, Guildford, Surrey, GU2 5XH, England

                    (prepared by G3RWL on behalf of AMSAT-UK)

The Amsat-UK Colloquium took place at UoS between 26-29 July - with over 200
people from 29 countries attending.

** AMSAT-OSCAR-13 **

Recent work has checked AO-13's orbital decay more fully using a detailed
mathematical model of Earth's gravitional field and the perturbations to AO-
13's orbit from the Sun & Moon.  The results show a mostly linear decay in
perigee altitude until 1992, a rise until early 1994 to a peak after which it
will plunge to 200 Km by mid-1996.

** RUSSIAN SATELLITES **

The RS14/RUDAK-2 launch has slipped until possibly October.  The 70cm link
will use an RHCP aerial while 2m will use a dipole.  Only one transponder will
be switched on at a time and that will normally be RUDAK; the analogue
transponder is considered to be a reserve.

** BADR-1 Satellite **

SUPARCO (Pakistan Space & Upper Atmosphere Research Commission) launched a
small UoSAT-2/FO-12 class microsatellite into orbit on 16 July.
Apogee/perigee at this time are about 198/982 km and will be 125/900 km by
November - so BADR-1 won't live long.  The telemetry is a near-identical
format to UO-11; with downlinks on 145.825 & 144.028 MHz (the latter frequency
is causing much concern as it does not conform to IARU band-plans).
...

** $BID **
Please use BID $UOSAT.218 for PR BBS use.
```

ASCII WOD

One of the biggest problems with telemetry reception is that any ground station can get data for the limited time that the 'bird' is in view. The designers of UoSat-2 attempted to solve this problem with their DSR experiment (Digital Store and Readout). This experiment is used to store: telemetry data for selected channels for an entire orbit; or a CCD picture; or particle counter experiment data. The data is then output in an error encoded format. Thus WOD (Whole Orbit Data) was developed to allow the monitoring stations to know what happens to particular onboard devices during an entire orbit. The WOD is usually composed of four to six channels of data that are sent in a very clever manner. The complete data set is divided into four sections. Each section sends data eight time units apart. If the data takes a noise hit or the signal fades a complete area of the whole orbit data is not lost. The other three sections will each have two of the remaining six time units of data that were hit. This allows the entire orbit profile to be constructed from just one section (1/4 of the data), albeit with a slight lost in resolution. The time unit for UoSat-2 (UO-11) at 1200 baud is 4.84 seconds. Figure 3.6 shows an abbreviated example of WOD received from UO-11. This data records the solar cell current for the (-Y, +Y, -X, +X) sides of the satellite. The complete set of data is formed by interleaving as much of the four sections as was captured. You will rarely be able to receive the entire WOD on one pass, but you may be able to get at least 2 partial and 1 complete sections. Figure 3.6 is a representative example, the complete data set received is found in Appendix D. The ... sequence symbolizes that data was omitted. The line that begins with '0000' is the channel identification frame. The first four digits are the hex number of time units into the sample. Then each group of three numbers that follow define a channel. The last two digits of each channel are the hex checksum for that channel. From Figure 3.7 you can see that this WOD is for channels 000, 010h, 020h, and 030h with a 5Bh checksum. Figure 3.7 takes the data from Figure 3.6 and rearranges it into its three sections. Spaces have been added between channels to aid in data identification. Notice that in section 1 the data is at time intervals 1 and 9; in section 2 at time intervals 5 and Dh; and section 3 at time intervals 3 and Bh. The uncopied section must have been at time intervals 7 and Fh. The WOD start time is sent in the telemetry bulletins. Figure 3.5 shows a portion of a UO-11 bulletin, notice WOD start time close to the center of the Diary Operating System information. The WOD is also sent in the 8-bit format, but in a more condensed form. This is discussed in the 8-bit data decoding section.

Figure 3.6 partial UO-11 WOD data

```
04795225225225 22A2
```

The checksum for the WOD is computed by doing hexadecimal addition of each byte in the line, including the checksum byte. The sum of this addition should be BBh. Notice that a leading zero needs to be inserted before the first digit of each of the channel bytes. Using the data in Figure 3.7 section 2 line one, we first break the data into separate bytes.

00 + 00 + 00 + 00 + 00 + 10 + 00 + 20 + 00 + 30 + 5B --> BBh, so the line was received correctly.

Figure 3.7 rearranged UO-11 WOD

```
                              section 2                       section 3
                          0000 000 010 020 030 5B    0000 000 010 020 030 5B
                          0005 516 421 181 520 CF    0003 516 177 248 522 B$
                          000D 333 514 162 520 D7    000B 455 517 134 520 E6
                          0015 135 514 517 521 15    0013 150 514 448 520 CD
                          001D 433 518 519 223 07    001B 351 515 518 260 B3
    section 1                        ...
0479 522 522 522 522 A2   0475 522 522 522 522 A6
0481 521 521 498 522 27   047D 522 522 522 522 9E
0489 256 516 439 521 58   0485 397 519 392 521 BF
0491 242 515 518 455 52   048D 202 515 517 521 CA
0499 521 521 521 353 56   0495 371 518 519 384 EC
```

Analyzing the UO-11 WOD

Whole Orbit Data (data from selected channels sampled and stored for an entire orbit) offers the most complete telemetry set. The best place to begin is to take the data for a single channel and graph it verses time. Study the graph and look for trends. Then try to explain them. Using the printouts of the decoded data, a piece of graph paper, and a fair amount of time will give you a good graph. The problem is the same thing needs to be repeated each time new data is looked at or the scale changes. This kind of operation is the reason spreadsheets were designed. By entering the data only once, you can filter only selected channels or groups of channels and instantly graph this selected data. This may require your learning to use a spreadsheet, but I guarantee you that you will spend much less time becoming familiar with the spreadsheet than doing 15 or 20 graphs by hand. Once you become comfortable with the spreadsheet you will be amazed at how creative you become. You can quickly manipulate the data and instantly graph it.

Figure 3.8 is a graph of channel 30h from the complete WOD (abbreviated in Figure 3.6). Channel 30h is the array current for side +X. Examining the graph, we see a series of current maximums. From the actual data we note that these occur every 8 samples. Using a sample rate of 4.84 seconds x 8 samples gives 38.72 seconds/current max. We know that when the solar cells are illuminated they produce current. This is the rate that the satellite is spinning or 1.55 rpm. We can also notice a long period from 781 to 1149 in which no current is generated. The satellite must have been in eclipse. Running the N4HY Quiktrak program, setting the date/time for 17 Aug 1990 00:00 and placing the display in fast mode we can watch when the satellite goes into eclipse. Taking the start time of the WOD from the UO11 bulletin and using the 4.84 second/sample rate we calculate the beginning of the eclipse to occur at 63 minutes after data collection begins. The no current time lasts 368 time units, so we predict that the eclipse should end at 92.6 minutes after collection begins. Returning to the N4HY program we see the eclipse flag come on at 01:02:25 and goes off at 01:33:10. So the observed and calculated match very closely, and confirms our telemetry analysis.
Figure 3.9 is the graph of the current for all four sides simultaneously. We see the graphical representation of the power generation transfer as the satellite spins. One other observation, side +Y generates about 220 mA less current at peaks than the other three sides.

Figure 3.8 Graph of one channel of UO-11 WOD data, see Appendix D.

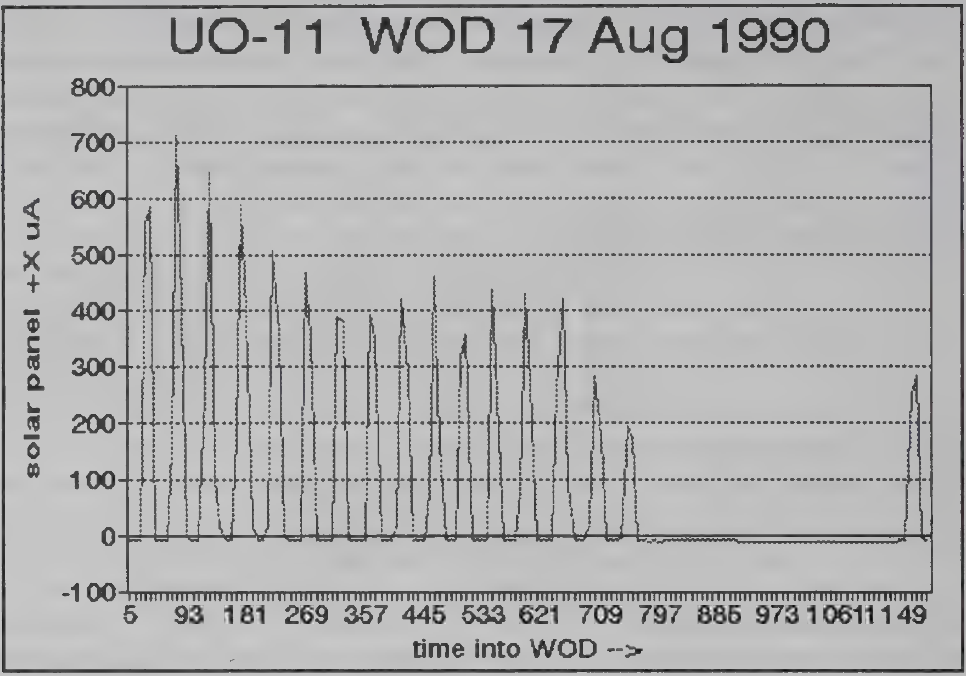
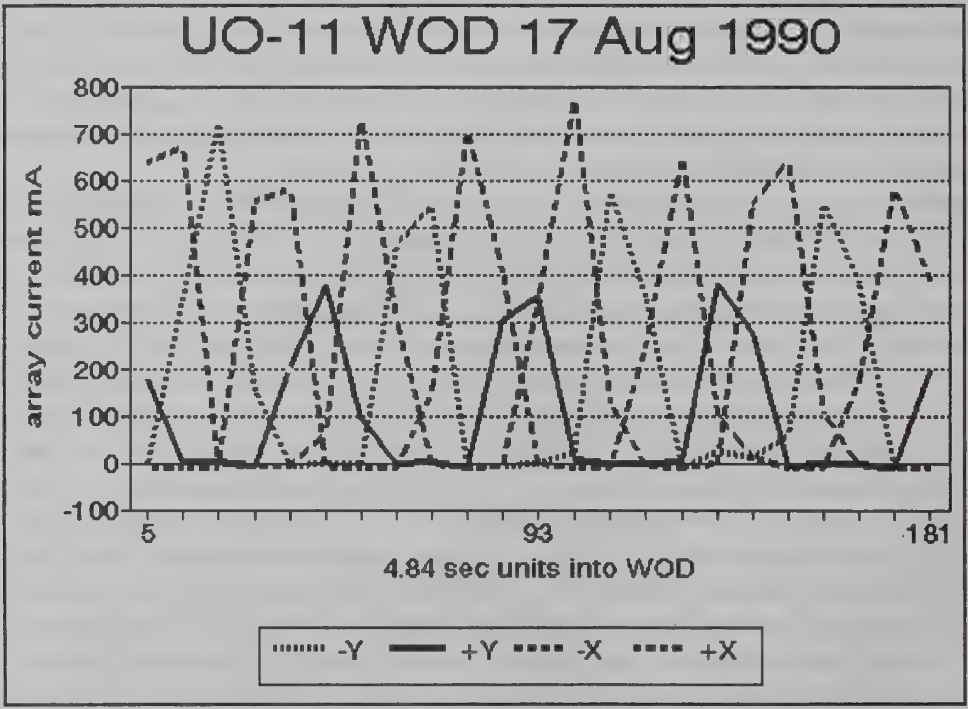


Figure 3.9 Graph of a section of all four channels of UO-11 WOD data, see Appendix D.



UO-11 8-bit packetized data

In order to provide the most data during the short window the satellite is in range, a more efficent method of formatting the data was necessary. A new multi-tasking operating system was implemented aboard UO-11 in the latter half of the 1980's. Changes in the data format of the engineering and scientific data were designed to:

1) packetize the data, with a header and checksum for each packet;
2) make the data format compatible with UoSAT-3; and
3) include a time stamp and frame identifier for each packet.

Data groups of 64 bytes each are set up. Sync bytes, an identification byte, a timestamp, frame count and checksum bytes are added to give a total of 77 bytes/packet. The packetization task of the operating system forms these packets from the raw data in memory. Then the information is downlinked as a regularly scheduled task in a very efficient manner. Since these packets are individually identified, a list of needed packets can be uploaded by the command stations. Then only the necessary packets to fill out the data set can be downlinked. The frames are separated from one another by a variable number of the 80h hexadecimal value.

Figure 3.10 General UO-11 packet format

S0 S1 ID T0 T1 T2 T3 T4 T5 F0 F1 D0...D63 C0 C1

S0 S1:	sync bytes
ID:	Identification byte
T0T1T2T3T4T5:	timestamp
F0 F1:	Frame counter
D0...D63:	64 data bytes
C0 C1:	checksum

Figure 3.11 Sample UO-11 hexadecimal data packets

```
5041 d3 434501070191 014e
fc6875fc6885fc6915fc6925fc6945fc6955f86975fc6985ec6995fc7005fc70
15fc7035fc7035fc7055fc7055fc7065ec7075fc7085fc7085fc7085fc7095fc
2864
8080808080808080

...

5041 03 014901070191 0001
0287056700060222028003960428046006510118064600620162000000000446
0459042504570108063902900663000000000455045000610 83e05fc05f40334
0b2a
80808080808008080808080808080
```

Figure 3.12 General UO-11 hexadecimal packet format description

S0S1 ID T0T1T2T3T4T5 F0F1 D0...D63 C0C1

S0S1	Sync bytes, 5041h for UO-11 (UoSAT-2) and 4534h for UoSAT-3. ASCII PA ASCII E4	
ID	Identification byte	
	01	Engineering frame. Hexadecimal version of computer status messages, 1 frame.
	02	Memory dump. Debugging tool, variable number of frames.
	03	Telemetry. TLM data in BCD format without the channel number, 3 frames.
	04	SEU data. Logged memory errors, 10 frames.
	05	Extended Engineering frame. Variable data, 2 frames.
	80h - FFh	WOD. This byte for the WOD always has the high bit set. The WOD ID byte starts at 80h and is incremented by 1 each time a new WOD survey is started. These increment up to FFh then rollover to 80h. UO-11 has 372 packets, UO-14 needs 352 packets.
T0T1T2T3T4T5	Date/Time stamp, BCD representation in SMHDMY (second, minute, hour, day, month, year) format.	
F0F1	Frame counter, each frame has a different count so that the frames location in the received file can determined. WOD frame counts are static until a new survey is started.	
D0...D63	Data, 64 data bytes.	
C0C1	Checksum, addition of all bytes after the 2 SYNC bytes through the DATA bytes, modulo 10000h	

UO-11 packetized data formats Engineering frame -- ID = 01

Figure 3.13 shows some of the DCE experiment messages and some of the Keplerian elements that are transmitted from UO-11. Following Figure 3.13 is a description of the Keplerian data format. Some control characters have been removed and some added to make the example easier to read.

Figure 3.13 sample UO-11 DCE messages and Keplerian elements from 2 Oct 1990.

```
DCE Message System V3.7
EDAC=F6  FREE MEM=052C  NEXT MSG=7FH  CMD#=C207  ERR=00  BANK 7F  RAM=0AF3 02DE
TO:G0/K8KA DE:MSG2 RE:REPORTS
To: All   de YN3UNI
To:YN3UNI De:WA9FMQ Re:Estadia Gianzero
TO:AP2SUP   DE:AP2PUL   RE:TESTING
To:YN3UNI De:K7PYK Re:KEPS09.23

kAO-10    90260.93188  26.01 184.39 0.5955 176.69 190.58  2.05882 -5.8E-7  5464
kUO-11    90268.04141  97.94 317.30 0.0012 293.80  66.20 14.65706  2.1E-5 35059
kRS-10/11 90267.77847  82.92 254.94 0.0011 195.50 164.58 13.72111  1.7E-7 16310
kAO-13    90263.62167  56.87 134.93 0.7030 236.13  37.14  2.09702 -1.2E-6  1740
kFO-20    90261.57385  99.04 290.43 0.0540 196.98 161.26 12.83160  0.0E0   2872
kUO-14    90266.22485  98.69 342.02 0.0011 229.30 130.73 14.28724  6.9E-6  3486
kUO-15    90207.07706  98.70 283.05 0.0011  43.71 316.50 14.28397  4.2E-7  2641
kAO-16    90265.36722  98.70 341.33 0.0011 229.89 130.14 14.28824  6.2E-6  3474
kDO-17    90266.41040  98.70 342.38 0.0011 225.72 134.31 14.28878  7.2E-6  3489
kWO-18    90266.11301  98.70 342.12 0.0011 227.59 132.43 14.28966  6.0E-6  3485
kLO-19    90267.43158  98.70 343.46 0.0012 222.95 137.08 14.29039  6.6E-6  3504
kSALYUT 7 90267.72900  51.60 157.13 0.0002 172.61 187.56 15.73631  7.6E-4 48047
kMIR      90267.82608  51.61 187.83 0.0027  82.58 277.82 15.59246  2.6E-4 26367
kHUBBLE   90267.52216  28.47 337.40 0.0006  89.32 270.81 14.85086  6.0E-5  2275
kBADR-1   90267.83173  28.49 196.10 0.0419 169.41 191.49 15.27044  3.7E-3  1069
kNOAA-9   90262.04297  99.17 264.08 0.0016 104.98 255.32 14.12671  6.0E-6 29723
kNOAA-10  90267.08975  98.60 292.80 0.0014 347.36  12.72 14.23738  6.2E-6 20868
kMET-2/17 90266.78156  82.54 272.08 0.0018  49.90 310.37 13.84372  1.2E-6 13382
kMET-3/2  90266.80743  82.54 207.64 0.0020  66.70 293.61 13.16905  3.9E-6 10393
kNOAA-11  90267.32480  98.99 215.79 0.0013  10.30 349.85 14.11727  1.1E-5 10295
```

Here are the labels for the fields of the Keplerian data in Figure 3.13.

```
KName     Epoch          INCL  RAAN  ECCY    ARGP    MA     MM          DECAY   REV#
kDO-17    90266.41040  98.70 342.38 0.0011 225.72 134.31 14.28878  7.2E-6   3489
kWO-18    90266.11301  98.70 342.12 0.0011 227.59 132.43 14.28966  6.0E-6   3485
```

This data set does not contain the semi-major axis, but it can be calculated from the Mean Motion (MM) using the following equation:

$$\mathbf{SMA = 42220 * MM^{(-2/3)}\ km}$$

UO-11 packetized data formats   Memory dump -- ID = 02

This data format was unavailable 12/90.

UO-11 packetized data formats Telemetry -- ID = 03

The telemetry channel labels and equations are the same as described in Table 3.1. The actual channel data is 2 BCD bytes per channel for analog channels 00 - 59. The digital status data for channels 60 - 67 are the 12 LSB's(least significant bits) of each 2 byte pair. No channel numbers are transmitted. It takes 134 packetized data bytes to represent one UO-11 telemetry frame (2 bytes x 68 channels = 136 data bytes). Since only 64 data bytes can be transmitted per packet, three packets are required to transmit the telemetry data. These three packets use frame counter values 00 - 02. Frame counter 00 has channels 00 - 31, frame counter 01 has channels 32 - 63, and frame counter 02 contains channels 64 - 67 with the remaining bytes filled with 00's.

Figure 3.14 sample UO-11 packetized telemetry data

```
5041 03 594801070191 0000
0519027006180413004700330019004600400035051902970000005700690527
0188052705740499051902200662000000010000009105220542046205190038
0923
8080808080808080

5041 03 014901070191 0001
0287056700060222028003960428046006510118064600620162000000000446
0459042504570108063902900663000000000455045000610 83e05fc05f40334
0b2a
80808080808008080808080808080

5041 03 034901070111 0002
04440160007e07000000000000083e05fc05f403340444 0160007e07000000000
0000000000000000000000000000000000000000000000000000000000000000
05c5
8080808080808080
```

UO-11 packetized data formats SEU -- ID = 04

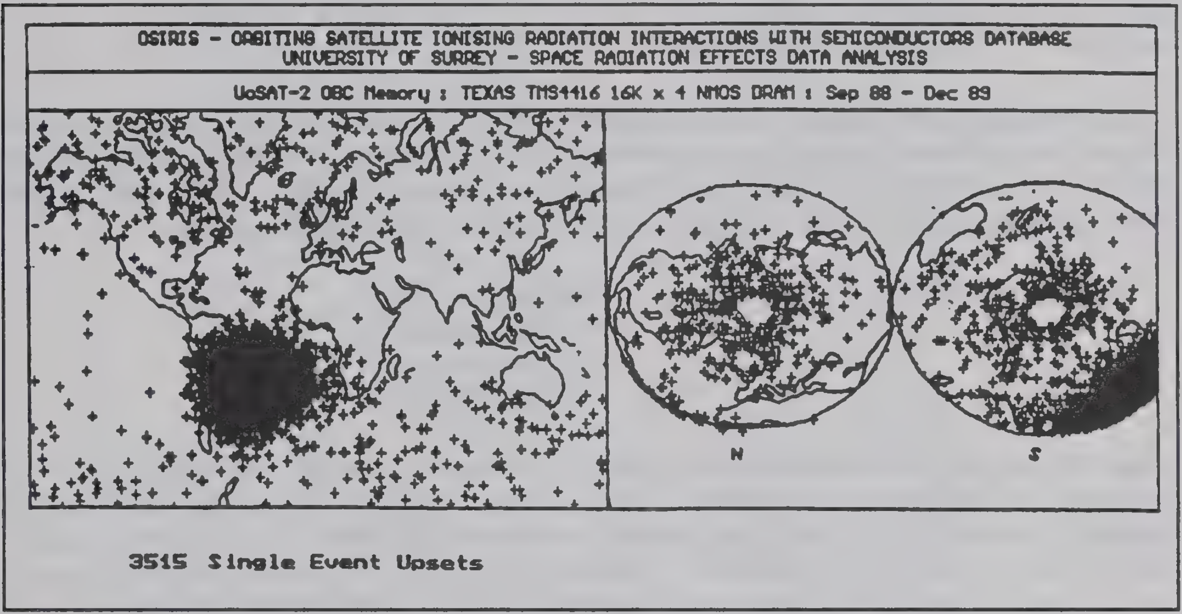
SEU(single event upset) is the onboard recording mechanism of the EDAC(error dectection and correction) circuit. The EDAC circuit constantly checks for errors to memory cells, when one is found it alerts the processor to log the events time and location. The actual correction of the memory cell occurs during the Memory WASH task of the Diary operating system. This task constantly goes through memory about every 8 minutes, correcting memory errors that have been flagged. The last 64 of these corrections are recorded and downlinked in the SEU packet. The time of the error, the memory location, and the total error count are recorded. Ten data bytes are required to store each event, so 10 packets are used to send the entire history. The format for the SEU packet data is:

T0 T1 T2 T3 T4 T5 A0 A1 C0 C1

T0 - T5:	same timestamp format described above
A0 A1:	address of the event (MSB LSB)
C0 C1:	total event counter (MSB LSB)

The "Proceedings of the AMSAT-UK Colloquium 1990" contains an excellent evaluation by Craig Underwood, G1WTW of UO-11 and it's SEU's data. The location of each SEU is plotted on a map of the world. Figure 3.15 is a reproduction of one of the figures from that paper. Notice the preponderance of SEU in the SAA (South Atlantic Anomaly). The February 1991 issue of "Sky and Telescope" contains an interesting explaination and description of the SAA.

Figure 3.15 UO-11 SEU plotted on a globe


OSIRIS - ORBITING SATELLITE IONISING RADIATION INTERACTIONS WITH SEMICONDUCTORS DATABASE
UNIVERSITY OF SURREY - SPACE RADIATION EFFECTS DATA ANALYSIS
UoSAT-2 OBC Memory : TEXAS TMS4416 16K x 4 NMOS DRAM : Sep 88 - Dec 89
N
S
3515 Single Event Upsets

UO-11 packetized data formats Extended Engineering data -- ID = 05

Two variable frames of data, mainly attitude control. Unable to obtain format.

UO-11 packetized data formats WOD -- ID = 80h - FFh

The most efficient and reliable use of the packetized data is for WOD. Since the number of channels sampled is variable, the data is often split between frames. If data collection is ongoing the remainder of the data storage area will be filled with zeros until the actual data is sampled. The first twenty bytes of WOD packetized data frame (0000) give the details of the survey, the remaining 44 bytes in frame 0 and all 64 bytes in the other 371 packets for UO-11 contain data only.

WOD packet frame 0000:
T0 T1 T2 T3 T4 T5 N C0 C1 C2 C3 C4 C5 C6 C7 C8 C9 X0 X1 X2 woddata

WOD packet frame 0001 - 371:
woddata

T0 - T5: survey start time, same timestamp format as above
N: the number of channels in the survey (max 10)
C0 - C9: the actual channel numbers in the survey
X0 - X2: not currently used
woddata: the actual WOD values

Each analog channel requires three digits for each data value. A total of three nibbles(half a byte), both nibbles in one byte plus one nibble in another. The nibble count begins with data byte 0 in frame 0 and progresses through the survey. Reading left to right we have the most significant digit (MSD), middle digit (MD), then least significant digit (LSD).

fc 68 75 fc 68 85 would convert to
fc6 for channel A
875 for channel B
fc6 for channel C
885 for channel D

Once the packet that identifies the number of channels surveyed and which channels were surveyed the WOD may be decoded. Using a four channel example, the first three nibbles belong to channel 1, the next three nibbles to channel 2, nibbles 7, 8 & 9 to channel 3 and nibbles 10, 11, and 12 to channel 4. Nibbles 13, 14 and 15 again belong to channel 1 and so on for the survey. These values can then be run through the appropriate decoding equations to get the values to examine.

fc 68 75 fc 68 85 fc 69 15 fc 69 25 fc 69 45 fc 69 55 converts to

fc6 875 fc6 885
fc6 915 fc6 925
fc6 945 fc6 955

Figure 3.16 Sample UO-11 packetized WOD

```
5041 d3 434501070191 014e
fc6875fc6885fc6915fc6925fc6945fc6955f86975fc6985ec6995fc7005fc70
15fc7035fc7035fc7055fc7055fc7065ec7075fc7085fc7085fc7085fc7095fc
2864
8080
5041 d3 444501070191 014f
7095fc7095fc7091fc7095fc7095fc7095fc7095fc7095fc7095fc7095fc7095
fc7085fc7085fc7085fc7085fc7095fc7095fc7095fc7095fc7095fc7095fc70
2c8b
80808080808080808080808080808080808080
5041 d3 454501070191 0150
95fc7085fc7095fc7095fc7095fc7105fc7105f87115fc7115fc5125fc7125fc
7135fc7135fc7145fc7155fc7165fc7175fc7185fc7185fc7195fc7205fc7215
2725
```

Table 3.1 UoSAT calibration equations
UoSat-2 Analog channels

Channel	Parameter	Calibration Equation
00	Solar array current -Y	I = 1.9(516 - N) mA
01	Nav mag X axis	H = ((0.1230 * N) - 60.4) uT
02	Nav mag Z axis	H = ((0.1261 * N) - 61.0) uT
03	Nav mag Z axis	H = ((0.1266 * N) - 62.0) uT
04	Sun Sensor 1	N Grey Coded Mask
05	Sun Sensor 2	N Grey Coded Mask
06	Sun Sensor 3	N Grey Coded Mask
07	Sun Sensor 4	N Grey Coded Mask
08	Sun Sensor 5	N Grey Coded Mask
09	Sun Sensor 6	N Grey Coded Mask
10	Solar array current +Y	I = 1.9(516 - N) mA
11	Nav mag (Wing) temp	T = (330 - N)/3.45 deg C
12	Horizon sensor	N 2 state output
13	435 MHz Beacon VCO control	V = N/200 V
14	DCE RAMUNIT current	I = (N - 70.4)/6.7 mA
15	DCE CPU current	I = (N - 187.1)/2.0 mA
16	DCE GMEM current	I = (N - 121.3)/2.1 mA
17	Facet temp +X	T = (480 - N)/5 deg C
18	Facet temp +Y	T = (480 - N)/5 deg C
19	Facet temp +Z	T = (480 - N)/5 deg C
20	Solar array current -X	I = 1.9(516 - N) mA
21	+10V line current	I = (0.97 * N) mA
22	PCM voltage +10	V = (0.015 * N) V
23	P/W logic current (+5V)	I = (0.14 * N) mA (N<+500)
24	P/W Geiger current (+14V)	I = (0.21 * N) mA
25	P/W Elec sp. current (+10V)	I = (0.096 * N) mA
26	P/W Elec sp. current (-10V)	I = (0.093 * N) mA
27	Facet temp -X	T = (480 - N)/5 deg C
28	Facet temp -Y	T = (480 - N)/5 deg C
29	Facet temp -Z	T = (480 - N)/5 deg C
30	Solar array current +X	I = 1.9(516 - N) mA
31	-10V line current	I = (0.48 * N) mA
32	PCM voltage -10	V = (0.036 * N) V
33	1802 comp curr (+10V)	I = (0.21 * N) mA
34	Digitalker current (+5V)	I = (0.13 * N) mA
35	145 MHz beacon power O/P	P = ((2.5 * N) - 275) mW (N>200)
36	145 MHz beacon current	I = (0.22 * N) mA
37	145 MHz beacon temp	T = (480 - N)/5 deg C
38	Command decoder temp (+Y)	T = (480 - N)/5 deg C
39	Telemetry temp (+X)	T = (480 - N)/5 deg C
40	Solar array voltage (+30v)	V = ((0.1 * N) - 51.6) V
41	+5V line current	I = (0.97 * N) mA
42	PCM voltage +5V	V = (0.0084 * N) V
43	DSR current (+5V)	I = (0.21 * N) V (N<=500)
44	Command RX current	I = (0.92 * N) mA
45	435 MHz beacon power O/P	P = ((2.5 * N) - 200) mW (N>175)
46	435 MHz beacon current	I = (0.44 * N) mA
47	435 MHz beacon temp	T = (480 - N)/5 deg C
48	P/W temp (-X)	T = (480 - N)/5 deg C
49	BCR temp (-Y)	T = (480 - N)/5 deg C
50	Battery charge/discharge curr	I = 8.8(N - 513) mA
51	+14V line current	I = (5 * N) mA
52	Battery voltage (+14V)	V = (0.021 * N) V
53	Battery cell volts (MUX) [16 readings per cycle]	V = 0.0053*N V for 10 individual cells V = 0.021*N V for total p.d. (repeated 6 times)
54	Telemetry current	I = (0.02 * N) mA
55	2.4 GHz beacon power O/P	P = ((N + 50)**2)/480 mW
56	2.4 GHz beacon current	I = (0.45 * N) mA
57	Battery temp	T = (480 - N)/5 deg C
58	2.4 GHz beacon temp	T = (480 - N)/5 deg C
59	CCD imager temp	T = (480 - N)/5 deg C

Table 3.1 UoSAT-2 Digital Status Channels

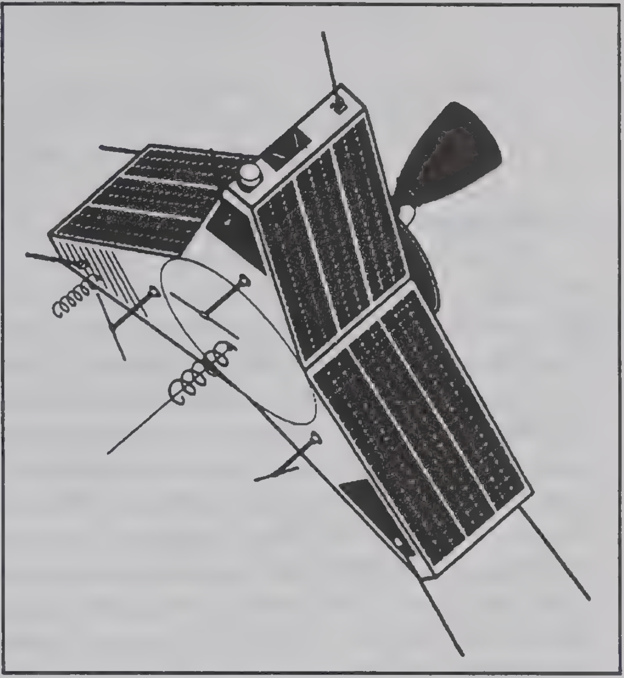
Channel	Bit	Function	0 / 1
60(MSB)	1	145 MHz General Beacon Power	OFF/ON
60	2	435 MHz Engineering Beacon Power	OFF/ON
60	3	2401 MHz Engineering Beacon power	OFF/ON
60	4	Telemetry channel mode select	Run/Dwell
60	5	Telemetry channel dwell address load	OFF/ON
60	6	Telemetry channel dwell address source	Gnd/Computer
60	7	Primary Spacecraft Computer power	OFF/ON
60	8	Primary Spacecraft Computer error count	Bit 1
60	9	Primary Spacecraft Computer error count	Bit 2
60	10	Primary Spacecraft Computer bootstrap	UART/PROM
60	11	Primary Spacecraft Computer error count	Bit 3
60(LSB)	12	Primary Spacecraft Computer bootstrap	A/B
61(MSB)	13	Gravity gradient boom deployment pyros	Safe/Arm
61	14	Gravity gradient boom deployment pyros	Fire/Hold
61	15	Gravity gradient boom deployment	Safe/Arm
61	16	Gravity gradient boom deployment	Deploy/Hold
61	17	Gravity gradient boom deployment	Extend/Retract
61	18	Attitude Control Magetorquers	Safe/Arm
61	19	Attitude Control Magetorquer -X	ON/OFF
61	20	Attitude Control Magetorquer -Y	ON/OFF
61	21	Attitude Control Magetorquer -Z	ON/OFF
61	22	Attitude Control Magetorquer	Reverse/Forward
61	23	435 MHz PSK Mode	NRZI/NRZIC
61(LSB)	24	2401 MHz PSK Mode	NRZI/NRZIC
62(MSB)	25	Attitude Control Magetorquers	High/Low power
62	26	Digitalker experiment power	OFF/ON
62	27	CCD camera experiment power	OFF/ON
62	28	CCD camera exper. integration period	Bit 0
62	29	CCD camera exper. integration period	Bit 1
62	30	CCD camera exper. video amp gain	Bit 0
62	31	CCD camera exper. video amp gain	Bit 1
62	32	DSR power	OFF/ON
62	33	DSR mode	Read/Write
62	32	DSR mode	Run/Reset
62	35	Radiation detectors Geiger-A EHT power	OFF/ON
62(LSB)	36	Radiation detectors Geiger-B EHT power	OFF/ON
63(MSB)	37	Radiation detectors Geiger-C EHT power	OFF/ON
63	38	Electron Spectrometer sensor EHT power	OFF/ON
63	39	DCE experiment power	OFF/ON
63	40	DCE experiment	Reset/Run
63	41	DCE experiment PROM select	A/B
63	42	DCE experiment CPU clock rate select	0.9/1.8 MHz
63	43	Navigation Magnetometer power	OFF/ON
63	44	Space Dust experiment power	OFF/ON
63	45	Status calibrate	
63	46	BCR status	A/B
63	47	435 MHz beacon modulation select	AFSK/PSK
63(LSB)	48	2401 MHz beacon modulation select	AFSK/PSK

Table 3.1 UoSAT-2 Digital Status Channels cont'

64(MSB)	49	Engineering data	Bit 1
64	50	Engineering data	Bit 2
64	51	Engineering data	Bit 3
64	52	Engineering data	Bit 4
64	53	Engineering data	Bit 5
64	54	Command Watchdog	Disable/Enable
64	55	Command Watchdog reset	Run/Reset
64	56	145 MHz beacon data select	A
64	57	145 MHz beacon data select	B
64	58	145 MHz beacon data select	C
64	59	145 MHz beacon data select	D
64(LSB)	60	145 MHz beacon data select	E
65(MSB)	61	145 MHz beacon data select	F
65	62	145 MHz beacon data rate	A
65	63	145 MHz beacon data rate	B
65	64	435 MHz beacon data rate	A
65	65	435 MHz beacon data rate	B
65	66	435 MHz beacon data rate	C
65	67	Particle / Wavecounter control	Count/Reset
65	68	VHF/UHF beacon lockout protection	Disable/Enable
65	69	Engineering data	Bit 6
65	70	Engineering data	Bit 7
65	71	Engineering data	Bit 8
65(LSB)	72	Engineering data	Bit 9
66(MSB)	73	P/W channel plate control	Bit 2
66	74	P/W channel plate control	Bit 1
66	75	P/W channel plate control	Bit 0
66	76	Space Dust (MSB)	
66	77	Space Dust	
66	78	Space Dust	
66	79	Space Dust	
66	80	Space Dust	
66	81	Space Dust	
66	82	Space Dust	
66	83	Space Dust (LSB)	
66(LSB)	84	DSR write cycle complete	NO/YES
67(MSB)	85	1802 CWO output	
67	86	1802 Telemetry port(MSB)	
67	87	1802 Telemetry port	
67	88	1802 Telemetry port	
67	89	1802 Telemetry port	
67	90	1802 Telemetry port	
67	91	1802 Telemetry port	
67	92	1802 Telemetry port	
67	93	1802 Telemetry port	
67	94	1802 Telemetry port	
67	95	1802 Telemetry port	
67(LSB)	96	1802 Telemetry port(LSB)	

February 27, 1991

AO-13



Name(s): OSCAR-13, P3-C(Phase 3-C)
Object #: 19216
International ID: 1988-051B
Launch: 15 June 1988
Period: 686.65 minutes, 11 hrs 26 min
Increment: 172.2 ° W
Orbit: Elliptical
Altitude: 8 hrs > 28,000 km
perigee: 1300 km
apogee: 39,000 km
Transponder: inverting
Operating modes: Mode B, J, L, & S
CW, RUDAK and voice
Telemetry: 400 bps PSK,
50 baud RTTY,
10 wpm CW

Sponsor: AMSAT international

Telemetry receiving equiptment:

CW: 145 MHz SSB receiver, preamp, pointable antenna, pencil & paper

RTTY: 145 MHz or 435 MHz SSB receiver, preamp, pointable antenna, RTTY decoder, computer or teleypte

PSK: 145 MHz or 435 MHz receiver, preamp, pointable antenna, 400 bps PSK demodulator, TNC, computer

Software: AO-13 RTTY decoding software from PROJECT OSCAR,
W9FMW PSK decoding software from AMSAT-NA,
PCE.EXE PSK decoding software from AMSAT-UK & PROJECT OSCAR

AO-13 Telemetry

OSCAR-13 transmits telemetry in three forms - BPSK, RTTY, and CW. The BPSK (Bi-Phase Shift Keyed) form is the most common and transmits the most complete set of data. The BPSK form is present 10 of every 15 minute segment. The CW and RTTY forms alternate in a 5 minute window each quarter hour. The PSK telemetry data is composed of 128 channels of data plus 4 available message blocks. These transmissions occur mainly on the beacon frequencies of:

145.812 MHz while in Mode B and

435.651 MHz while in mode JL.

Telemetry transmission schedule each hour:

00 - 05 mode B CW, mode J RTTY
05 - 15 PSK
15 - 20 RTTY
20 - 30 PSK
30 - 35 mode B CW, mode J RTTY
35 - 45 PSK
45 - 50 RTTY
50 - 00 PSK

Receiving AO-13 telemetry

Eight hours of each eleven hour orbit of AO-13 are spent greater than 28,000 km from the earth. So to reliably receive telemetry it is necessary to have a gain antenna pointed at the satellite, a preamp as close to the antenna as possible, and low loss coax to get the data from the preamplifier to the receiver. These are necessary to lose as little of the weak signal as possible. Determine which mode the satellite is in, by finding the current MA and looking up the mode in the quarterly operationing schedule. Once a signal with a good signal to noise ratio is presented to the receiver, tune the receiver to the currently active beacon frequency. Tune for maximum signal strength. This frequency will be slightly off the listed frequency due to Doppler shift. Next adjust the receiving antenna for maximum signal. Switch antenna polarity (if possible) for the strongest, least fading signal. As you receive data continue to track the signal both with the receiver and the antenna. While the satellite is in the outer half of it orbit (MA 64 - 192) adjustments approximately every 10 minutes is often enough. When the satellite is close to the earth the receiving equipment requirements are less stringent. The satellite moves faster across the sky though, so antenna tracking must occur more often. The Doppler shift continues to constantly affect the receive frequency.

AO13 General Telemetry Format

Telemetry from AO-13 is sent in 512 byte blocks, in 8 lines of 64 bytes each. The blocks or frames are identified by the first byte of the block. This letter is always followed by a space (ASCII <20>). The defined block types are: K, L, M, N, Q, Y, or Z. Spaces are used to fill out lines in the message blocks. It is necessary for the receive station to add <CR><LF>s to the message blocks after each 64th character to make them more readable. The analogue data in the Q and Y blocks must be run through the appropriate decoding/calibration equations to get the correct channel values.

Figure 5.1 Phase 3-C general telemetry format

[synchronizing characters]
line 0 [Block type][identifing message] [UTC time] [AMSAT day number]
line 1 [safety information word] [transponder status] [command number]
line 2 decimal data for channels 40 - 46
line 3 blank line
line 4 [channels 00 - 0F in decimal, or channels 00 - 1F in hex telemetry data]
line 5 [channels 10 - 1F in decimal, or channels 20 - 3F in hex telemetry data]
line 6 [channels 00 - 2F in decimal, or channels 40 - 5F in hex telemetry data]
line 7 [channels 00 - 3F in decimal, or channels 60 - 7F in hex telemetry data]
[CRC checksum]

synchronizing characters: in BPSK $39, $15, $ED, $30
in RTTY these are RYRYRY's,

Line #0

block type: Single character label describing the type of data in the telemetry frame/block
See Figures 5.2 through 5.10 for examples of each block type

K, L, M, N blocks: these are the text/message blocks used by the command stations send messages to one another; to provide bulletins about changes to the craft; to give the current mode schedule and Bahn lattitude/longitude.
It is necessary to add a <CR><LF> to these message blocks at 64 character intervals when displaying on the ground. If the 7th bit is set, this means that the ASCII character is to be highlighted.

Q block type: all 128 analog telemetry data channels in hexadeciaml format. This data needs to be run through the calibration equations. Some of the hexadecimal values are in a compressed format, where the bit value is significant (status points).

Y block type: the first 64 of the 128 analog telemetry channels in decimal format. This data also needs to be run through the calibration equations.

Z block type: RTTY telemetry which is the first 60 of the 128 analog data channels but also includes some data messages.

Other special message blocks appear infrequently. These occur in response to a command from one of the command stations.

UTC time: UTC time in hh:mm:ss or hh.mm.ss format

AMSAT day number: decimal number of days since 1 JAN 1978 (1 JAN 1990 = 4382)

Line #1

Safety Information Word: (emergency flags) 16 bit flags, bits 07 - 00 are channel $56

bit position	function	
15	---	
14	not used	
13	---	
12	set if Sun angle exceeds limit, > 50 degrees	
11	set if High temperature, battery or transponder	
10	set if Command loss (watchdog, needs a command within 30 days)	
09	set if Extremely low power QRPP mode	
08	set if Low power, QRP mode	
07	MSB of memory soft error count	---
06	memory soft error count	
05	LSB of memory soft error count	
04	--- not used	channel
03	set if Mode S squelch open	$56
02	set if RUDAK out (lock)	
01	S/C plug status 0=safe, 1=arm	
00	set if LIU power on	------

Transponder status: this is channel $5E

07 set if Passband OFF (beacons and mode J +3 dB)
06 set if Low power transponder on
05 --+ BPSK source 00 no BPSK 10 ranging(bit 5,4)
04 --+ for GB (EB don't care) 01 EB source(bit 5,4)
03 set if Engineering Beacon ON
02 set if DPSK OFF
01 set if 170 Hz General Beacon FSK
00 set if General Beacon OFF

Command number: number of commands sent to the satellite, hexadecimal value ($00 - $FF)

line 2: decimal values of channels $40 - $46 (2MUX0 - 2MUX6)

line 3: this line is blank, used as a separator

line 4 - 7: K, L, M, & N blocks are ASCII data, 6 lines of 64 characters
Q block are 128 (00h - 7Fh) channels of hexadecimal data
Y block is the first 64 channels of data in decimal format, 16 channels per line, left justified, no leading zeros, a data value of 7 normally means that no data is available
Z block is RTTY data, the first 60 (7Fh) channels, sent in decimal, 10 channels per line, left justified, no leading zeros, a data value of 7 normally means that no data was available

CRC: Based on the CCITT polynominal, see Appendix H.

==

Figure 5.2 Sample AO13 PSK telemetry data Y block

```
Y  HI, THIS IS AMSAT OSCAR 13                       19:22:41   3894
#00A6   #0020   #0193
64  9   255 166 17  230  0

193 7   152 7   193 7   165 115 200 7   136 7   100 7   153 29
7   7   138 54  9   7   136 136 16  7   139 151 116 7   137 7
147 134 136 7   220 149 134 7   75  149 134 165 227 132 127 55
179 129 126 126 62  141 132 7   13  127 124 7   208 133 125 7
```

Figure 5.3 Sample AO13 PSK telemetry data Q block, the most common
`128 data bytes are hexadecimal, displayed here as 2 characters each`

```
Q  HI, THIS IS AMSAT OSCAR 13                       04:51:16  4398
#0066   #0020   #0090
64  1  0   3   8   221 0

203B0843C258332E664C20646520564B354147522031334A616E393020323033
30757463204A616D657320473352554820 2D205468616E6B7320696E20616476
616E636520666F72207461207668652053533 22F455320646120766961204D61
696C2E205965732049206469642072656365697665207468652050412069 6E66
```

Figure 5.4 Sample AO-13 telemetry -- K block, normally WOD, the 384 bytes of WOD data are displayed as 2 bytes each

```
K Whole Orbit TLM Data V1.1  Samples: 8    Captured Channel: 72
0A0A0A0A0A0A0A0A0A0A070A0C0A0B090A0A0A0A0A0A0A0A0A0A0B0A0A0A0B0A
0A0A0B3A0A202020202020202020202020202020202020202020202020202020
2020202020202020202020202020202020202020202020202020202020202020
2020202020202020202020202020202020202020202020202020202020202020
2020202020202020202020202020202020202020202020202020202020202020
2020202020202020202020202020202020202020202020202020202020202020
2020202020202020202020202020202020202020202020202020202020202020
2020202020202020202020202020202020202020202020202020202020202020
2020202020202020202020202020202020202020202020202020202020202020
2020202020202020202020202020202020202020202020202020202020202020
2020202020202020202020202020202020202020202020202020202020202020
2020202020202020202020202020202020202020202020202020202020202020
Start= 13:40:14 4580  #40B0     Last= 02:32:46 4581  #41D0
```

Figure 5.5 Sample AO-13 PSK telemetry message L block

```
L de G3RUH 1990 Jul 01.  AO-13 transponder schedule from Jul 04
Vode-B  : MA   3 to MA 165 |   Perigee eclipses Jul 09 - Oct 09.
Mode-JL : MA 165 to MA 190 |   Mode-B users:  please help mode-S
Mode-LS : MA 190 to MA 195 |   experimenters by:
Mode-S  : MA 195 to MA 200 | <<-- a) DONT transmit here
Mode-BS : MA 200 to MA 205 | <<-- b) DO use QRP here
Mode-B  : MA 205 to MA 240 |   Next attitude change Oct 15 to
Omnis   : MA 240 to MA  60 |   ALON/ALAT 180/0.         ,  JRM
```

Figure 5.6 Sample AO-13 PSK telemetry message M block

```
M de VK5AGR 03Aug90 2120utc Peter DB2OS - I have also had a num
ber of requests from Northern Hemisphere users to have the Mode
B beacon OFF during Mode S operation. I agree that it would be
worth a try to see if it will reduce the interference to Mode S
users by Mode B users trying to locate their downlink signals on
Mode B because they think that the Mode B transponder is ON be-
cause the Mode B beacon is ON. Have you checked to see whether
or not it is possible to implement? 73s Graham
```

Figure 5.7 Sample AO-13 PSK telemetry message N block

```
N de G3RUH 90 Sep 05 170-0 utc.  Tnx FAX Graham  will send graph
of WOD of Vbat (currently in K block).  Meantime I concur that
the Sun angle will reach 34 deg and lowest illumination 83%.
As the Vbat (at 87%) is already rather low during the L-S-B
(MA195-205) area and will worsen, we will have to delete mode S
until Oct 15th's  re-orientation.  (Obviously we can't reorient
before then due to perigee eclipses = no Sun Sensor sub-system).


      73 James
```

AO-13 CW

In deference to the traditional use of CW telemetry, AO-13 transmits CW bulletins. Only while in Mode B, 10 wpm CW is transmitted on the hour and the half hour for approximately 5 minutes. The AO-13 Technical manual refers to CW telemetry as a possiblity. I have not copied any telemetry and James Miller tells me that only messages are sent.

Figure 5.8 AO-13 CW bulletin

```
@ HI THIS IS AMSAT OSCAR 13  04 JUL 90
AO13 TRANSPONDER SCHEDULE
MODE B  MA 003 TO 165
MODE JL MA 165 TO 190
MODE LS MA 190 TO 195
MODE S  MA 195 TO 200
MODE BS MA 200 TO 205
MODE B  MA 205 TO 240
OFF     MA 240 TO 003
OMNIS   MA 240 TO 060
```

AO-13 RTTY Telemetry

AO-13 RTTY telemetry is sent at 50 baud, standard 170 Hz RTTY shift (OK to use 200 Hz shift), UnShift On Space OFF or disabled, USB on 70cm and LSB on 2m. Many of the 'RTTY decoding boxes' have both an HF and a VHF switch. The VHF position on many of these boxes uses a 1000 Hz shift and the HF positon is a 170 Hz shift. The 1000 Hz shift positon will NOT correctly decode the AO13 RTTY signal. So although you are receiving the signal on VHF/UHF use the 170 Hz shift position, even if it is labeled HF.

Each data block begins with RYs followed by the header, the numerical data, and concluding with a text message. The cycle then repeats, usually with a different text message following the numeric data. There are slight differences from the PSK data format: the time elements are separated by periods; the saftey word, transponder status and command number begin with a period; the data is decimal and in six lines of 10 channels each; and a text message immediately follows the data. The data is the first 60 (3Fh) channels.

You may notice some three-letter code groups in the data, usually beginning with a 'Q'. These occur when the 'figures shift' character was missed by the receiver or decoding box. The 'figures shift' could have occurred before the data reception began and the decoding unit was in letters mode. The letters can be converted by hand/computer, but the data should be corrected on the text part of the block and catch the 'figures shift' in the next group sent.

Fig. 5.9 Sample AO13 RTTY telemetry data from July 4, 1990.

```
RYRYRYRYRYRYRYRYRYRYRYRYRYRYRY
RYRYRYRYRYRYRYRYRYRYRYRYRYRYRY
RYRYRYRYRYRYRYRYRYRYRYRYRYRYRY
Z  HI. THIS IS AMSAT OSCAR 13
      20.45.29  4568
.0026   .0000   .0171

64  14  0   1   13  229 0

235 7   155 135 193 7   150 82  200 7
137 7   116 7   151 31  7   7   156 7
12  7   138 62  18  7   141 69  118 7

138 7   169 136 139 57  134 141 141 7
137 147 140 18  227 133 127 7   179 137
134 7   76  140 139,141 14  130 130 207
HI THIS IS AMSAT OSCAR 13 04JUL90
AO13 TRANSPONDER SCHEDULE
MODE B   MA 003 TO 165
MODE JL MA 165 TO 190
MODE LS MA 190 TO 195
MODE S  MA 195 TO 200
MODE BS MA 200 TO 205
MODE B  MA 205 TO 240
OFF    MA 240 TO 003
OMNIS   MA 240 TO 060
```

Project OSCAR has a program available to decode AO-13 RTTY telemetry. This program was written in uncompiled BASIC and requires either GW-BASIC or BASICA to run. The original author was Howard Sodja, W6SHP, with the program converted to Microsoft BASIC by David Medley, KI6QE. The program itself is well documented and provides a good model for those wishing to write their own decoding program or modify this one. Project OSCAR requests a modest donation that will further the amateur satellite effort. The menu allows the user to get a list of files in the current directory, which is very useful if you forget the filename you used to save the data. The RTTY data files must be edited before processing and conform to a fixed format. This editing may be done with any ASCII editor or any editor that has a non-document/text mode. There is a useful program tutorial selection included in the menu. The program left my EGA monitor in a different color state when I exited. This was corrected by the command: mode co80 <CR>. The decoded data from the RTTY telemetry is displayed on three separate screens. The user is prompted to press the ENTER key to go to the next screen of data. Figure 5.10 has examples of the three screens.

Figure 5.10 sample output of Project OSCAR AO-13 RTTY decoding program

```
                      =================  Screen #1  ===================
AO-13 Telemetry Data For
Sept. 18 1990 at 21.45.31 UTC, Orbit # Unknown:

Safety Flags: None

Communications Systems:

Transponder Status: Passband On,  +14 V Bus Current = 1213 MA
Antennas On Line  : 2 M High Gain,  70 CM High Gain
Mode B : 2 M TX Output= 3 Watts, TX Amp Temp = 18 C
         70 CM RX AGC = 0 dB,  RX Temp = 22 C
         Transponder +9 V Supply = 9126 MV
Mode JL: 70 CM TX Output = 0 Watts,  TX Amp Temp = 16 C
Mode L : 24 CM RX AGC = 0 dB,  RX Temp = 18 C
         Transponder +9 V Supply = 8943 MV
Mode S : TX Off,  Beacon Off,  Squelch Closed,  Sense Low,  Temp = 5 C
RUDAK  : Off, Temp = 11 C

Press [ENTER] Key To Continue.

                      =================  Screen #2  =====================
Electrical Power Systems:

Solar Cell Panels (Arms):
   1 = 0 MA, 2 = 0 MA, 3 = 0 MA, 4 = 0 MA, 5 = 0 MA, 6 = 0 MA
   Solar Panels Out (BCR Input) = 35905 MV
Battery Charge Regulator (BCR) Operation:
   BCR OSC #1 Off   OSC #2 On, On Line   BCR Temp = 22 C
   Battery Status, Main Connected, AUX Disconnected
   BCR Output (Main Battery) = 14310 MV at 1286 MA
   AUX Battery Voltage = 314 MV
   Battery Charge Current = 0 MA
   Battery Temp, Main = 17 C, AUX #1 = 14 C, AUX #2 = 18 C
   Knee Voltage Setpoints, Battery = 4394 MV, Array = 1529 MV
+10 Volt Regulator  = 10108 MV at 82 MA  (Computer Systems)
+14 Volt Regulator  = 14295 MV

Press [ENTER] Key To Continue.

                      =================  Screen #3  ==================
Spacecraft Status:

Spin Rate (Z Axis) = 24 RPM
Magnetorquers and Antenna Relay +14 V Bus Current = 0 MA
Earth Sensor Sensitivity Threshold = 1.2 V
SERI Light Sensors: Load Resistors = 7.5 Ohms
                    Top (ANT) +Z = 8 MA, Bottom (Motor) -Z = 358 MA
Command Number Count = 428
Memory Soft Error Count = 4
ARM 1: Solar Panel 1 = 9 C  Wall = 14 C  Skin Top = 3 C, Bottom = 21 C
       2 M TX AMP = 18 C   70 CM TX AMP = 16 C   70 CM RX = 22 C
       24 CM RX = 18 C   Mode S XPONDER = 5 C
ARM 2: Solar Panel 3 = 9 C   Wall = 10 C   +Z SERI Platform = 3 C
       Sensor Electronic Unit = 15 C   AUX Batteries #1 = 14 C, #2 = 18 C
       BCR = 22 C
ARM 3: Solar Panel 5 = 10 C   Helium Tank = 13 C  Main Battery = 17 C
       RUDAK = 11 C   IHU (Computer) = 14 C   Nutation Damper = 13 C
Central Body: Fuel Tanks, Top (N204) = 16 C  Bottom (AZ50) = 18 C

Do You Wish To Enter Another Block Of Telemetry? (Y/N) ?
```

AO-13 BPSK Telemetry

AO-13 spends most of its time transmitting BPSK telemetry. The telemetry data is sent in a 512 byte, 400 bit/second Bi-Phase Shift Keyed (BPSK or PSK) stream. The PSK data is demodulated and converted into data by a 400 baud PSK demodulator. The data is ASCII, hexadecimal, and decimal ASCII. The type of data block/frame is described by the first letter of each block. The telemetry from AO-13 is too large to reasonably decode all of it by hand. The same approach to decoding the telemetry, as all the other satellites I have discussed, is used. Take the received analog values from the Q and Y blocks and substitute it into the appropriate calibration equation. Break the status channels into bits and assign them to their respective status points. See Appendix I for sources of available PSK demodulators and PSK telemetry receiving/decoding software.

The Q block data is the most common and sent as hexadecimal data. The K, L, M, N, & Y block data are all sent in ASCII. The normal order of telemetry block transmissions is: Q, K, Q, L, Q, M, Q, N, Q, Y, Q, K, Q, etc. The Q blocks are sent approximately every 27 seconds.

Table 5.1 contains the calibration equations for AO-13 for those that want to decode the telemetry by hand or write their own programs. There are two very good programs available from AMSAT-UK and AMSAT-NA.

AO-13 PSK Telemetry Decoding Software

Jack Mathais, W9FMW, has provided a versatile AO-13 data capture and decoding program. The program, TLM.EXE, provides 6 choices to process the telemetry. The received data can be stored to a file or displayed on the screen or both. The six choices are:

<1> Long report with text blocks
<2> Short report with text blocks
<3> Text blocks only
<2> Long report - 'Q' blocks only
<4> Short report - 'Q' blocks only
<6> No Processed report

Figure 5.11 displays an example of choice 2 hardcopy, a Q block long report.

P3C.EXE was written by Charles Mowle, VK5ACM, and provides a good realtime telemetry display of the telemetry. It has 2 special requirements: 1) must use the G3RUH PSK modem; and 2) it is necessary to have the DCD line, or one of the handshake lines connected for the software to decode the telemetry. Data logging to disk is an option. The screen is divided into 3 windows with the latest ASCII (K, L, M, N, or Y) block displayed in the one on top. Modem status conditions are in a small window in the upper left. Here the DCD activity and number of bytes received in the current block are displayed. The third window contains one of 5 selected groupings of the telemetry. These groups are: 1) Communications; 2) Navigation; 3) Power; 4) Temperature; and 5) S band Transponder. When a different group is selected, you must wait until the next Q block is received to go to the new display. The data from the last Q block is not retained. Hard copy is obtained by pressing the <shift> PRINT SCREEN combination. Figure 5.12 shows some sample screens of the P3C program.

Figure 5.11 Sample output from Jack Mathais, W9FMW, AO-13 telemetry decoding program

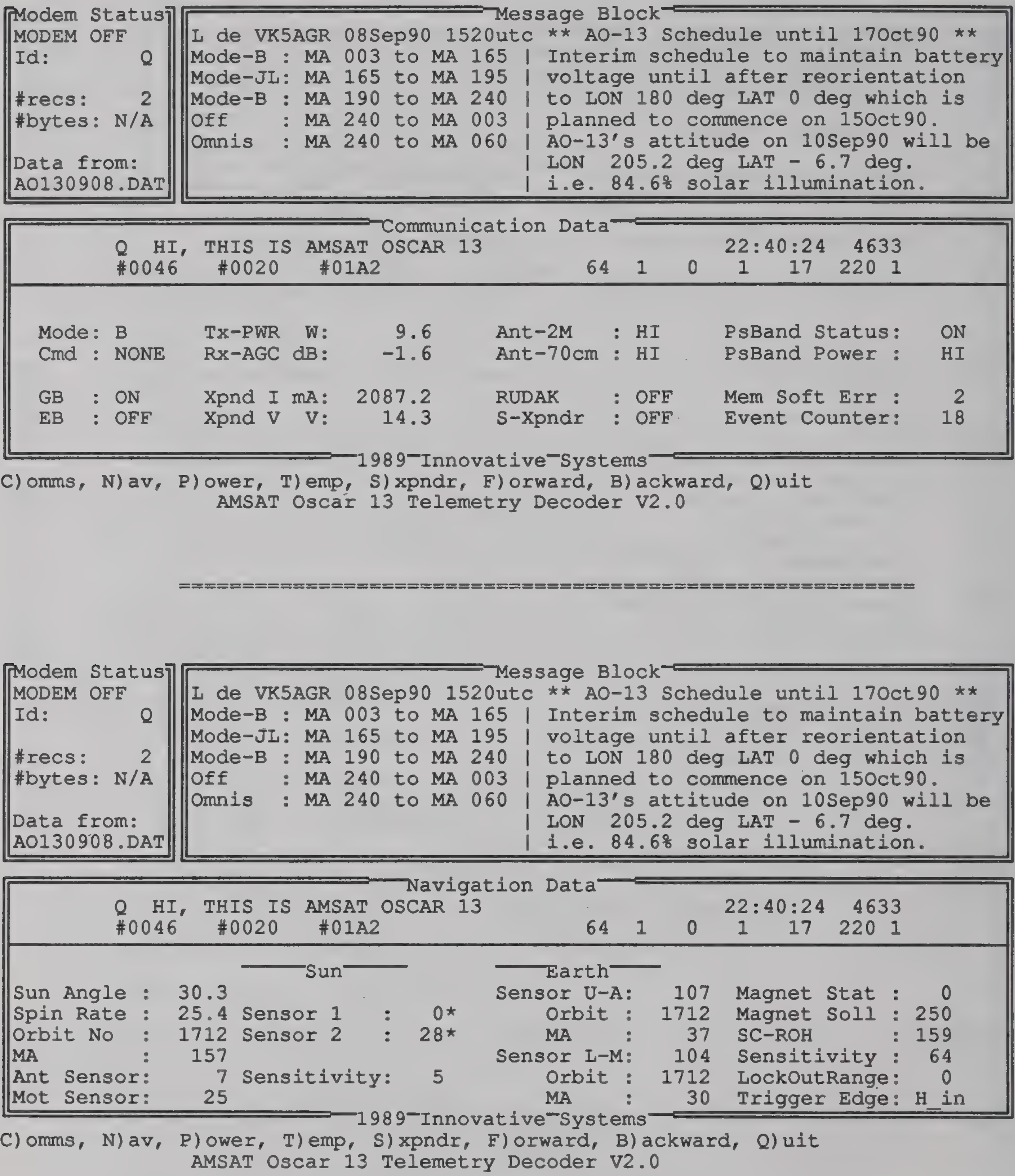
```
   PSK Telemetry Record for July 18, 1990  Time 02:39:58 UTC

2 Meter Transmitter Average Power Output  (Watts)............     10.8
2 Meter Transmitter Power Amplifier Temperature (Degrees C)..     26.3
70cm Transmitter Average Power Output (Watts)................      0.0
70cm Receiver Temperature  (Degrees C).......................     18.7
70cm Receiver  AGC  (db).....................................     -7.5
70cm Transmitter Power Amplifier Temperature (Degrees C).....     17.0
23cm Receiver Temperature  (Degrees C).......................     17.0
23cm Receiver AGC  (db)......................................      0.0
Mode S Transponder Temperature  (Degress C)..................     12.3

Main Battery Voltage (BCR output)............................     14.5
Main Battery Temperature  (Degrees C)........................      9.9
Battery Charge Current  (Ma).................................      0.0

Auxillary Battery Voltage (Volts)............................      2.7
Auxillary Battery #1 Temperature  (Degrees C)................      9.4
Auxillary Battery #2 Temperature  (Degrees C)................     11.1

+9 Volt Supply to Mode B Transponder  (Volts)................      9.1
+9 Volt Supply to 23cm Transponder  (Volts)..................      9.0
+10 Volt Regulator Current (Ma)..............................     82.5
+10 Volt Regulator Voltage  (Volts)..........................     10.1
+14 Volt Rail Current to Transponder (Ma)....................   2184.3
+14 Volt Regulator Voltage  (Volts)..........................     14.4
+14 Rail Current to Torquers, Antenna Relay, LIU (Ma)........      0.0

Solar Panel #1 Current  (Ma).................................    635.9
Solar Panel #2 Current  (Ma).................................      0.0
Solar Panel #3 Current  (Ma).................................      0.0
Solar Panel #4 Current  (Ma).................................      0.0
Solar Panel #5 Current  (Ma).................................      0.0
Solar Panel #6 Current  (Ma).................................    873.7

Solar Panel Out and BCR Input Voltage (Volts)................     30.6

Solar Panel #1 Temperature  (Degrees C)......................      9.4
Solar Panel #3 Temperature  (Degress C)......................      8.2
Solar Panel #5 Temperature  (Degrees C)......................      8.2

RUDAK Temperature  (Degrees C)...............................      7.0
IHU Temperature  (Degrees C).................................      9.4
SEU (Sensor Electronic Unit) Temperature  (Degrees C)........     10.5

BCR Oscillator #1 Status ....................................       ON

BCR Oscillator #2 Status ....................................      OFF

BCR (Active) Output Current  (Ma)............................   2621.2
BCR Temperature (Degrees C)..................................     19.3

He Tank High Pressure  (Bar).................................      0.0
He Tank Temperature  (Degrees C).............................      8.2
He Tank Low-side Pressure Control Voltage   (Volts)..........      0.0


Top (+Z) Skin Temperature of Arm #1 (Degress C)..............      4.1
Bottom (-Z) Skin Temperature of Arm #1  (Degress C)..........     11.1

Wall Temperature in Arm #1  (Degrees C)......................     14.6
Wall Temperature in Arm #2  (Degrees C)......................      7.6
```

Figure 5.11 continued

```
Page 2 of PSK Telemetry Record for July 18, 1990  Time 02:39:58 UTC

N2O4 Tank Pressure  (Bar - Abs)............................          0.0
N2O4 Tank Temperature (Degrees C)..........................         10.5
AZ-50 Tank Temperature  (Degrees C)........................         11.7
Motor Valve Status.........................................       CLOSED

Spin Rate   (RPM)..........................................         32.8

Top (+Z) Photocell Sensor     (Millivolts)..................          0.0
Bottom (-Z) Photocell Sensor  (Millivolts)..................          0.0

+Z Platform Temperature - SERI Experiment  (Degrees C).......          2.9

Nutation Damper Temperature  (Degrees C)....................          7.0


Magnet Status..............................................          OFF
Magnet Soll................................................          250
Spin Count.................................................          195
Mode.......................................................            B
Mode S transponder.........................................          OFF
General Beacon.............................................           ON
Engineering Beacon.........................................          OFF
2 meter antenna............................................           HI
70 cm antenna..............................................           HI
Transponder Passband Status................................           ON
Transponder Passband Power.................................           HI
Memory Soft Error Count....................................            1
Mean Anomaly...............................................          210
Orbit Number...............................................         1601
```

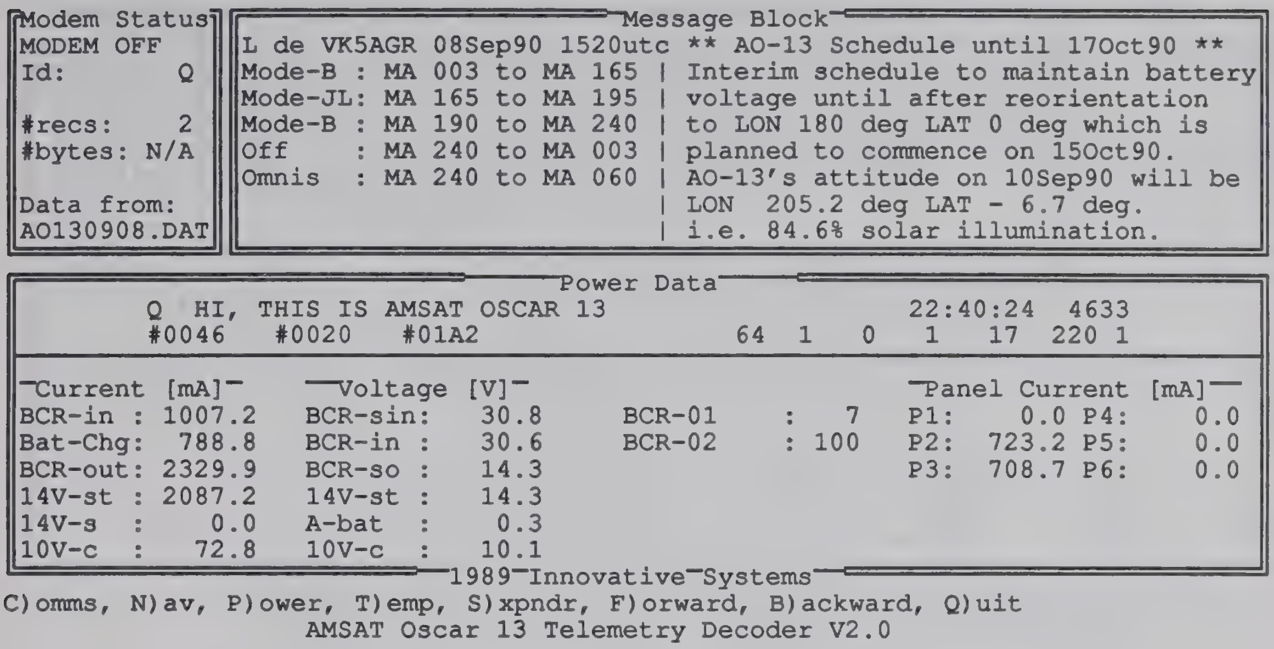
```
Q  HI, THIS IS AMSAT OSCAR 13                    02:39:58  4581
#0026   #0020   #017A
64  9   0   1   17  230 0

 193   7 152   7 193   7 165 105 200   7 136   7 100   7 153  32
   7   7 138   7   7   7 136 123   7   7 139 145 116   7 137 195
 148 134 136   7 207 149 134   7 142 149 134   7 226 132 127   7
 179 133 139 146 188 145 138  23  45 141 125   7 208 140 132   7
  64   9   0   1  17 230   0   0  10   3 195  84   5  40  65  32
  65   0 152   0 148   0  38  61   0 205   3   5   0   0  32   0
   0 250   0  30   9 210  65   6  14   0  40   2 229  17   1   0
   0   0   1   0   0   0   1   0   0   0   1   0  38   0  17   0
```

Figure 5.12 P3C.EXE software screen displays



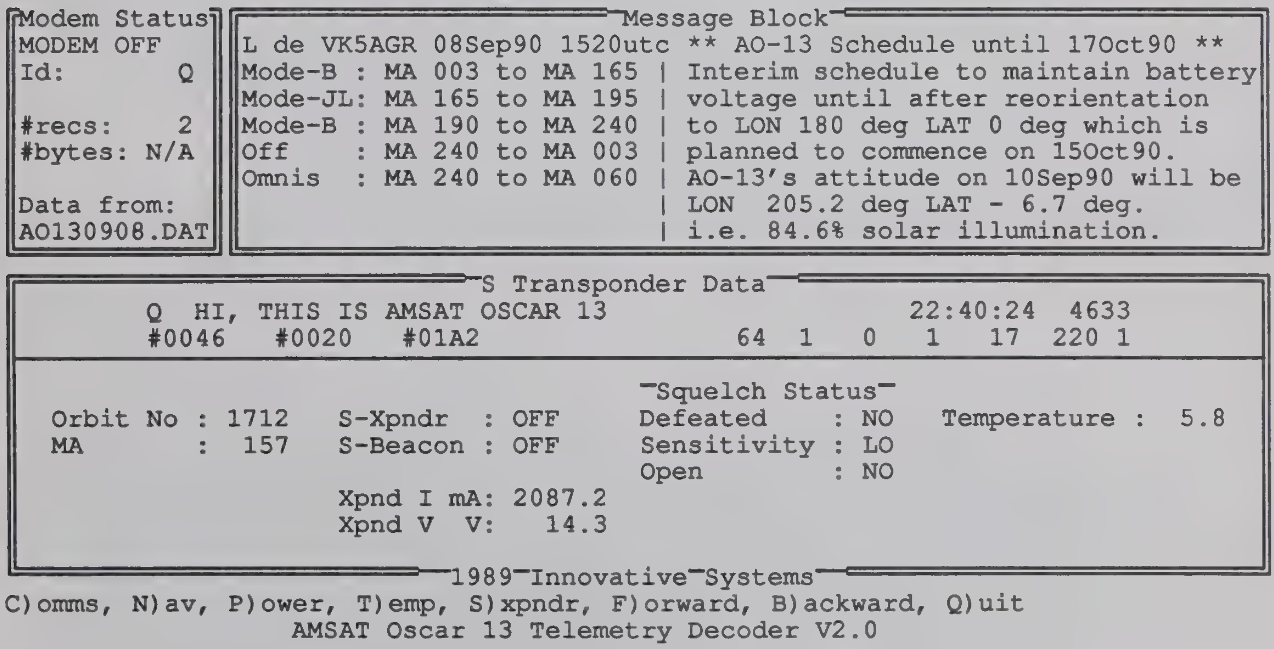
```
Modem Status   Message Block
MODEM OFF      L de VK5AGR 08Sep90 1520utc ** AO-13 Schedule until 17Oct90 **
Id:        Q   Mode-B : MA 003 to MA 165 | Interim schedule to maintain battery
               Mode-JL: MA 165 to MA 195 | voltage until after reorientation
#recs:     2   Mode-B : MA 190 to MA 240 | to LON 180 deg LAT 0 deg which is
#bytes: N/A    Off    : MA 240 to MA 003 | planned to commence on 15Oct90.
               Omnis  : MA 240 to MA 060 | AO-13's attitude on 10Sep90 will be
Data from:                               | LON  205.2 deg LAT - 6.7 deg.
AO130908.DAT                             | i.e. 84.6% solar illumination.

                    Communication Data
      Q  HI, THIS IS AMSAT OSCAR 13                       22:40:24  4633
      #0046   #0020   #01A2                64  1   0   1   17  220 1

  Mode: B      Tx-PWR  W:      9.6     Ant-2M    : HI     PsBand Status:   ON
  Cmd : NONE   Rx-AGC dB:     -1.6     Ant-70cm  : HI     PsBand Power :   HI

  GB  : ON     Xpnd I mA:  2087.2      RUDAK     : OFF    Mem Soft Err :    2
  EB  : OFF    Xpnd V  V:    14.3      S-Xpndr   : OFF    Event Counter:   18

                    1989 Innovative Systems
C)omms, N)av, P)ower, T)emp, S)xpndr, F)orward, B)ackward, Q)uit
                 AMSAT Oscar 13 Telemetry Decoder V2.0


          ==========================================================


Modem Status   Message Block
MODEM OFF      L de VK5AGR 08Sep90 1520utc ** AO-13 Schedule until 17Oct90 **
Id:        Q   Mode-B : MA 003 to MA 165 | Interim schedule to maintain battery
               Mode-JL: MA 165 to MA 195 | voltage until after reorientation
#recs:     2   Mode-B : MA 190 to MA 240 | to LON 180 deg LAT 0 deg which is
#bytes: N/A    Off    : MA 240 to MA 003 | planned to commence on 15Oct90.
               Omnis  : MA 240 to MA 060 | AO-13's attitude on 10Sep90 will be
Data from:                               | LON  205.2 deg LAT - 6.7 deg.
AO130908.DAT                             | i.e. 84.6% solar illumination.

                    Navigation Data
      Q  HI, THIS IS AMSAT OSCAR 13                       22:40:24  4633
      #0046   #0020   #01A2                64  1   0   1   17  220 1

                 Sun                     Earth
Sun Angle :  30.3                      Sensor U-A:   107  Magnet Stat :   0
Spin Rate :  25.4 Sensor 1    :   0*      Orbit :  1712  Magnet Soll : 250
Orbit No  :  1712 Sensor 2    :  28*      MA    :    37  SC-ROH      : 159
MA        :   157                      Sensor L-M:   104  Sensitivity :  64
Ant Sensor:     7 Sensitivity:   5        Orbit :  1712  LockOutRange:   0
Mot Sensor:    25                         MA    :    30  Trigger Edge: H_in
                    1989 Innovative Systems
C)omms, N)av, P)ower, T)emp, S)xpndr, F)orward, B)ackward, Q)uit
               AMSAT Oscar 13 Telemetry Decoder V2.0
```

Figure 5.12 continued P3C.EXE software screen displays



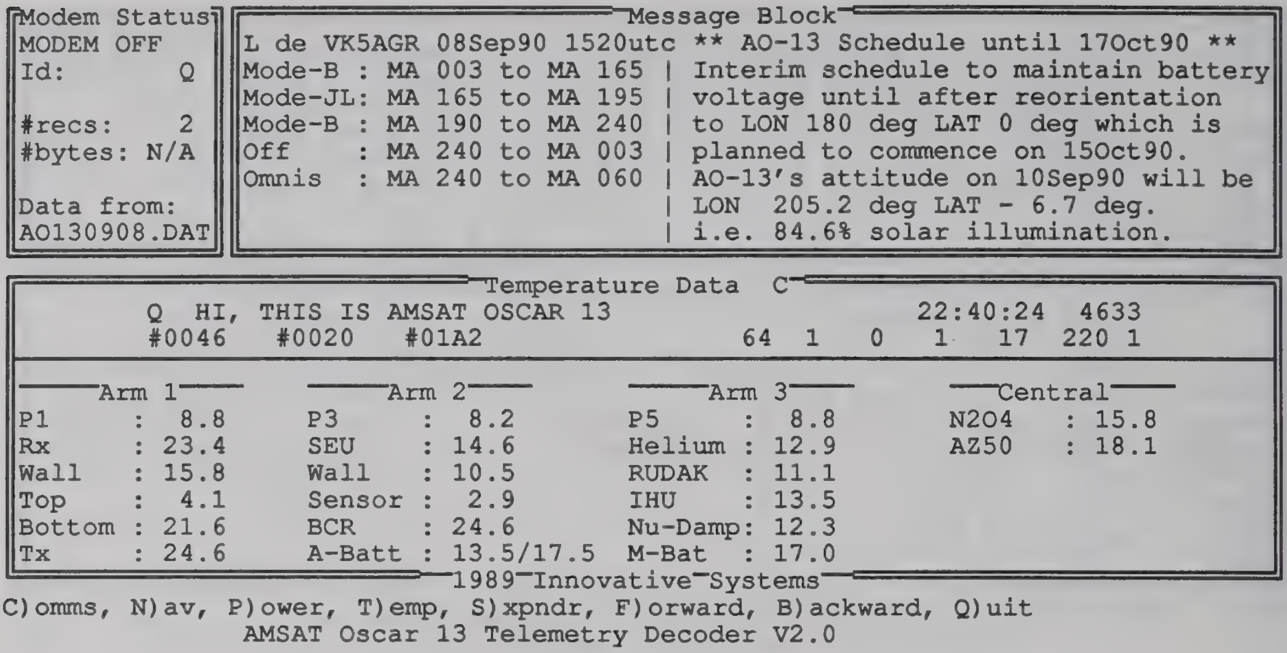
```
Modem Status                              Message Block
MODEM OFF      L de VK5AGR 08Sep90 1520utc ** AO-13 Schedule until 17Oct90 **
Id:        Q   Mode-B : MA 003 to MA 165 | Interim schedule to maintain battery
               Mode-JL: MA 165 to MA 195 | voltage until after reorientation
#recs:     2   Mode-B : MA 190 to MA 240 | to LON 180 deg LAT 0 deg which is
#bytes: N/A    Off    : MA 240 to MA 003 | planned to commence on 15Oct90.
               Omnis  : MA 240 to MA 060 | AO-13's attitude on 10Sep90 will be
Data from:                               | LON  205.2 deg LAT - 6.7 deg.
AO130908.DAT                             | i.e. 84.6% solar illumination.

                                Power Data
       Q  HI, THIS IS AMSAT OSCAR 13                          22:40:24  4633
       #0046   #0020   #01A2                   64  1   0   1   17  220 1

Current [mA]        Voltage [V]                               Panel Current [mA]
BCR-in : 1007.2   BCR-sin:   30.8     BCR-01     :   7     P1:      0.0 P4:     0.0
Bat-Chg:  788.8   BCR-in :   30.6     BCR-02     : 100     P2:    723.2 P5:     0.0
BCR-out: 2329.9   BCR-so :   14.3                          P3:    708.7 P6:     0.0
14V-st : 2087.2   14V-st :   14.3
14V-s  :    0.0   A-bat  :    0.3
10V-c  :   72.8   10V-c  :   10.1
                             1989 Innovative Systems
C)omms, N)av, P)ower, T)emp, S)xpndr, F)orward, B)ackward, Q)uit
                   AMSAT Oscar 13 Telemetry Decoder V2.0
```

===



```
Modem Status                              Message Block
MODEM OFF      L de VK5AGR 08Sep90 1520utc ** AO-13 Schedule until 17Oct90 **
Id:        Q   Mode-B : MA 003 to MA 165 | Interim schedule to maintain battery
               Mode-JL: MA 165 to MA 195 | voltage until after reorientation
#recs:     2   Mode-B : MA 190 to MA 240 | to LON 180 deg LAT 0 deg which is
#bytes: N/A    Off    : MA 240 to MA 003 | planned to commence on 15Oct90.
               Omnis  : MA 240 to MA 060 | AO-13's attitude on 10Sep90 will be
Data from:                               | LON  205.2 deg LAT - 6.7 deg.
AO130908.DAT                             | i.e. 84.6% solar illumination.

                           S Transponder Data
       Q  HI, THIS IS AMSAT OSCAR 13                          22:40:24  4633
       #0046   #0020   #01A2                   64  1   0   1   17  220 1

                                        Squelch Status
  Orbit No : 1712   S-Xpndr  : OFF     Defeated    : NO   Temperature :  5.8
  MA       :  157   S-Beacon : OFF     Sensitivity : LO
                                       Open        : NO
                    Xpnd I mA: 2087.2
                    Xpnd V  V:   14.3

                             1989 Innovative Systems
C)omms, N)av, P)ower, T)emp, S)xpndr, F)orward, B)ackward, Q)uit
                  AMSAT Oscar 13 Telemetry Decoder V2.0
```

Figure 5.12 continued P3C.EXE software screen displays



```
╔Modem Status╗╔═══════════════════════════Message Block════════════════════════╗
║MODEM OFF   ║║L de VK5AGR 08Sep90 1520utc ** AO-13 Schedule until 17Oct90 ** ║
║Id:        Q║║Mode-B : MA 003 to MA 165 | Interim schedule to maintain battery║
║            ║║Mode-JL: MA 165 to MA 195 | voltage until after reorientation   ║
║#recs:     2║║Mode-B : MA 190 to MA 240 | to LON 180 deg LAT 0 deg which is   ║
║#bytes: N/A ║║Off     : MA 240 to MA 003 | planned to commence on 15Oct90.    ║
║            ║║Omnis   : MA 240 to MA 060 | AO-13's attitude on 10Sep90 will be║
║Data from:  ║║                           | LON  205.2 deg LAT - 6.7 deg.      ║
║AO130908.DAT║║                           | i.e. 84.6% solar illumination.     ║
╚════════════╝╚════════════════════════════════════════════════════════════════╝
╔════════════════════════════Temperature Data  C═══════════════════════════════╗
║        Q  HI, THIS IS AMSAT OSCAR 13                   22:40:24  4633        ║
║        #0046   #0020   #01A2                64  1   0   1   17  220 1        ║
╟──────────────────────────────────────────────────────────────────────────────╢
║─────Arm 1────    ─────Arm 2────      ─────Arm 3────      ───Central───       ║
║P1     :  8.8     P3     :  8.2       P5     :  8.8       N2O4   : 15.8       ║
║Rx     : 23.4     SEU    : 14.6       Helium : 12.9       AZ50   : 18.1       ║
║Wall   : 15.8     Wall   : 10.5       RUDAK  : 11.1                           ║
║Top    :  4.1     Sensor :  2.9       IHU    : 13.5                           ║
║Bottom : 21.6     BCR    : 24.6       Nu-Damp: 12.3                           ║
║Tx     : 24.6     A-Batt : 13.5/17.5  M-Bat  : 17.0                           ║
╚═══════════════════════════1989═Innovative═Systems════════════════════════════╝
C)omms, N)av, P)ower, T)emp, S)xpndr, F)orward, B)ackward, Q)uit
               AMSAT Oscar 13 Telemetry Decoder V2.0
```

AO-13 WOD decoding

Normally K blocks from AO-13 contain WOD (Whole Orbit Data). This data is a log of data values for a selected channel stored over multiple orbits. The format is somewhat confusing and cryptic, so bear with me. Refer to Figure 5.13 during the explanation.
AO-13 WOD contains 384 bytes of sampled data plus 128 bytes for both the introductory line and the terminating Start/Stop line. This means that the data is divided into 8 lines of 64 characters each. Since I cannot display hexadecimal characters in one character position the 384 data bytes are each represented as two characters each. The hexadecimal character 20h is also the ASCII space character, so blank characters are spaces.

Line 1. Samples: [n] specifies the decimal sample interval in MA units (/256)
Channel: [n] specifies the decimal channel number sampled

Line 2 - 13. The 384 sampled values. These are sent as hexadecimal values (00h - FFh). The table is initialized to 20h or the <SP> (ASCII space character).

Line 14. Start= hh:mm:ss dddd #oozz Last= hh:mm:ss dddd #oozz

Start is the UTC time the WOD started.
dddd is the AMSAT DAY NUMBER, which is the number of days since 01 JAN 1978 (4382 = 1 JAN 1990, 4747 = 01 JAN 1991).
oo is the hexadecimal, low byte of the orbit number, telemetry channels 67h,66h contain the total number of orbits in hexadecimal
zz is the hexadecimal MA count that begins the sampling
Note: the sampling only takes place on even divisions of MA / Samples. or MA MOD Samples = 0. So using the data in Figure 5.13 sampling began at MA B0h or 176.

Last is the UTC time that the last sample was taken.
dddd is the AMSAT DAY NUMBER, which is the number of days since 01 JAN 1978 (4382 = 1 JAN 1990, 4747 = 01 JAN 1991).
oo is the hexadecimal, low byte of the orbit number, telemetry channels 67h,66h contain the total number of orbits in hexadecimal
zz is the current hexadecimal MA count, not necessarily the last sample taken.

Figure 5.13 sample AO-13 WOD

```
K Whole Orbit TLM Data V1.1  Samples: 8    Captured Channel: 72
0A0A0A0A0A0A0A0A0A0A070A0C0A0B090A0A0A0A0A0A0A0A0A0A0B0A0A0A0B0A
0A0A0B3A0A202020202020202020202020202020202020202020202020202020
2020202020202020202020202020202020202020202020202020202020202020
2020202020202020202020202020202020202020202020202020202020202020
2020202020202020202020202020202020202020202020202020202020202020
2020202020202020202020202020202020202020202020202020202020202020
2020202020202020202020202020202020202020202020202020202020202020
2020202020202020202020202020202020202020202020202020202020202020
2020202020202020202020202020202020202020202020202020202020202020
2020202020202020202020202020202020202020202020202020202020202020
2020202020202020202020202020202020202020202020202020202020202020
2020202020202020202020202020202020202020202020202020202020202020
Start= 13:40:14 4580  #40B0     Last= 02:32:46 4581  #41D0
```

Using the G3RUH PSK demodulator

Appendix E has construction hints, tuneup procedure and modifications for the G3RUH 400 bps modem. There is a very useful modification by Ed Krome, KA9LNV referenced. It describes adding carrier and clock lock LEDs to the demodulator. This allows you to keep the switch in the tune position and keep a check on whether the carrier and clock are locked or not. This modification will greatly aid in tuning in the signal.

The following tuning description assumes that the G3RUH demodulator has a ±100 uA tuning meter, 500 kΩ fine tune pot and the data block LED connected.

Follow the standard tuning conventions for getting the best beacon signal. Center the tuning knob, then place the PSK unit meter selector switch in the CLOCK LOCK position. Retune the receiver until the signal gives a full scale reading on the meter. This says the PSK demodulator PLL has locked with the received clock signal. If the needle bounces in and out of lock the chances are that the telemetry data will not be completely valid. It is necessary to have a solid lock signal to get valid data. If the unit will not lock try peaking the antenna, using a preamp, switching the antenna polarity or using a lower loss coax to get a stronger signal. Once the clock lock is solid, switch to the CARRIER LOCK position. Check that the meter is 'pegged' or full-scale also. Finally change the switch to the TUNE position and fine tune to center the needle. It is possible to have a false lock. A good check for false lock is to make slight movements of the TUNE knob left and right of center. The meter needle will swing far left and far right through the center position with the fine tune adjustment moved left and right of center if the lock is true. The DCD data light(LED) should light approximately every 10 seconds.

Appendix E also contains a schematic of a serial adapter circuit to make the unit compatible with a standard RS-232C serial link.

==

Conventions used in Table 5.1 for the AO-13 calibration equations:

Bytes are counted in the followings ways:

C - unsigned count (0 to +255)
Cs - signed count (-128 to +127, 2s complement)
Cx - signed count (+63 to -192, #3F = +63, #FF = -1, #80 = -128,
#7F = -129, #40 = -192, modified 2s complement)

All temperature channels are decoded identically using the following decoding relationship:
Temp: T = (C-120) / 1.71 Celsius

Current channels are linear, but have different calibrations for 1A, 2.5A and 5A max. current:

1A: I = (C-15)*4.854 mA
2.5A: I = (C-15)*12.135mA
5A: I = (C-15)*24.27 mA

Table 5.1. Phase 3C (AO-13) Channel calibration equations:

Byte	Channel	Calibration	Remarks
00	Uin-BCR	U=(C-10)*167mV	U-Panel: +0.6V @ 0.35A +0.7V @ 1A
01	Tx-PWRout-L	Average power=(261-C)^2 / 724 Watts	rectified envelope voltage.
02	T-Rx-U	Temp	Mode-B reveiver temperature.
03	---		
04	Uout-BCR	U=(C-10)*79.5mV	BCR output voltage.
05	---		
06	T-TX-U	Temp	Mode-B transmitter temperature.
07	I-14V-ST	5A	Transponder separation bus.
08	U-10V-C	U=(C-10)*53.2mV	Computer supply
09	Press He-Hi	off	Helium tank pressure.
0A	T-IHU	Temp	Integrated Housekeeping Unit
0B	I-14V-S	1A	Separation bus, 14V that supplies torquer and LIU.
0C	BCR-Oscill1	>~6=OK	BCR status. No count = not working. Typically C=80.
0D	Press He-Lo	off	Helium regulator output.
0E	T-BCR	Temp	Battery Charge Regulator.
0F	I-10V-C	1A	10V continuous power supply.
10	BCR-Oscill2	As channel 0C	
11	Press Tank	off	N2O4 tank pressure.
12	T-SEU	Temp	Sensor Electronics Unit
13	IbatCharge	2.5A	Positive Current to battery.
14	L-Sensor (A)	U=(C-10)*8.53mV	Light-Sensor Antenna Side.
15	Motor Valve	off	
16	T-ABAT1	Temp	Auxiliary battery 1
17	I-BCR-OUT	5A	14V line to battery and other consumers.
18	L-Sensor (M)	U=(C-10)*8.53mV	Light-Sensor Motor Side.
19	---		
1A	T-ABAT2	Temp	Auxiliary battery 2
1B	I-BCR-IN	Equivalent to total current of all panels, not available due to sensor failure.	
1C	Spin rate	(C>131, Spin rate=479/(C-109)-2 rpm)pre-launch (C<=131, Spin rate=(131-C)*0.85+20 rpm)formulas Spin rate = (141.54 - C*0.968)rpm (post-launch formula) Sensor angular position oscillator. Lock indication channel #47	
1D	Rx-L-AGC	Gain reduction=(C-75)^2 / 1125 dB	
1E	T-MBAT	Temp	Mean battery (normally in use)
1F	I-Panel6	1A	Solar panel 6
20	Tx-PWRout-U	Average power=(287-C)^2 / 1796 Watts	As channel 01.
21	T-He-Tank	Temp	
22	T-Panel1	Temp	
23	I-Panel5	1A	
24	Rx-U-AGC	Gain reduction=(C-71)^2 / 2465 dB	
25	T-Tx-L	Temp	Mode-JL transmitter.
26	T-Panel3	Temp	
27	I-Panel4	1A	
28	---		
29	T-Rx-L	Temp	Mode-L receiver.
2A	T-Panel5	Temp	
2B	I-Panel3	1A	
2C	U-14V-ST	U=(C-10)*66.8mV	Transponder separation bus.
2D	T-RUDAK	Temp	RUDAK temperature.
2E	T-top	Temp	Arm 1, Antenna side.
2F	I-Panel2	1A	
30	U-9V-U	U=(C-10)*54mV	Internal 9 volt bus from Mode-B transponder.

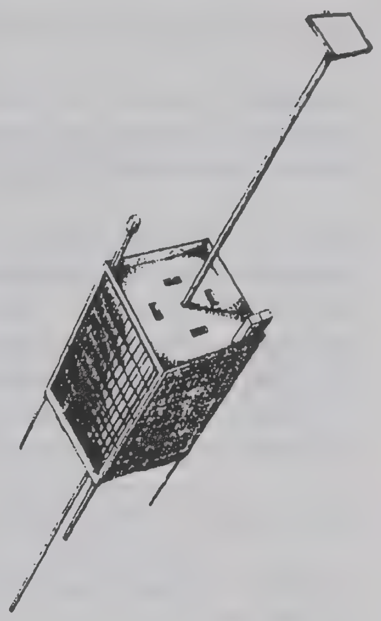
```
31   T-wall-arm2     Temp
32   T-bottom        Temp                Arm 1, Motor side.
33   I-Panel1        1A
34   ---
35   T-wall-arm1     Temp
36   T-N2O4          Temp
37   ---
38   U-ABAT          U=(C-10)*78.5mV  Auxiliary battery.
39   T-S-xpnder      Temp                Mode-S transponder.
3A   T-L-Sensor      Temp                Light sensor antenna side.
3B   ---
3C   U-9V-L          U=(C-10)*45.4mV  As channel 30, Mode-L
3D   T-AZ50-Tank     Temp
3E   T-nutation damper  Temp             Arm 3.
3F   ---

  ================   END of Y and Z block channels   =================

40   ES-Sensitivity 2MUX0                Earth Sensor sensitivity
                                         threshold.
                    bit   significance
                    0 LSB  20mV
                    1      37mV          Hysteresis 200mV
                    2      75mV          Threshold  600mV
                    3     150mV
                    4     300mV
                    5     600mV
                    6     1.2V
                    7 MSB 2.4V

41   Antenna/SERI   2MUX1                Antenna relays and SERI resistors.
                    bit   significance
                    0 LSB Hi-gain  2m  to U
                    1     Hi-gain 70cm to L
                    2     --+ SERI-1  load resistor for
                    3     -+! SERI-2  both Light-Sensors
                           !! resistance
                           00  7.5 Ohm
                           01  3.9 Ohm
                           10  2.3 Ohm
                           11  5.9 Ohm

42   RUDAK-Status   2MUX2                IN-B (ex Motor-PWR).
                    C=82, Standard-ROS  (S)
                    C=78, Emergency-ROS (N, Not-ROS)
                    C=80, Primitive-ROS (P)

43   S&RUDAK-CNTL   2MUX3                Mode-S and RUDAK interface.
                    bit   significance
                    0 LSB RUDAK OFF
                    1       "   NMI/
                    2       "   Byte Clock
                    3       "   Byte count reset
                    4      ---
                    5     Mode-S Beacon ON
                    6       "    Squelch defeated
                    7 MSB   "    Squelch Hi Sensitivity

44   BCR-Sin        2MUX4                Array voltage offset.
                    U=29.1+(Cs*100)mV  (16.3V...41.8V)

45   BCR-Sout       2MUX5                Battery knee voltage offset.
                    U=14.98+(Cx*20)mV  (11.14...16.2V = 192...63)
```

```
46   BCR-relays     2MUX6
                    bit   significance
                    0 LSB BCR-2 ON
                    1     Auxiliary battery charging
                    2     Auxiliary battery connected,
                          Main battery disconnected.


47   SS-1           C=255 or C=0, PLL locked
                                     Sun-Sensor angular position
                                     oscillator, Slit antenna side.
48   SS-2           Time offset from SS-1
49   Flag-SS        C=1, SS-1        Sun sensor data.
                    C=2, SS-2
4A   SPIN-RAW                        Raw spin count (1/256).
4B   Sensor-control bit   significance  (OUT4)
                    0 LSB --+ MUX-CTRL for sensor elec. module
                    1     -+!
                           !!
                           00 - Sun data
                           01 - spin ref./spin counter
                           10 - ES lower beam
                           11 - ES upper beam
                    2     Earth sensor positive edge select.
                          (Strobes value of spin count at transition.)
                    3     Motor Instrumentation ON.
                          (Pressure sensors, motore valve indicator.)
                    4     0.3V Sun Sensor Sensitivity
                    5     0.6V  "    "          "
                    6     1.2V  "    "          "
                    7 MSB 2.4V  "    "          "
                          (Max threshold #F = 1 solar constant)
4C   SS-correction
4D   Last ES-A      Z                last ES-pulse Antenna side.
4E     "            O#               (Orbit number and MA value)
4F   Last ES-M      Z                last ES-pulse Motor side.
50     "            O#               (Orbit number and MA value)
51   Lockoutrange   Within +- C counts from sun sensor pip, earth
                    sensor handler ignores data (Spin count 1 circle=
                    256 counts.)
52   ES-A           Strobed spin count at edge selected,
                                     Antenna Side beam.
53   Update Flag1   Indicates update,Antenna Side beam.
54   ES-M           As channel 52    Motor Side beam.
55   Update Flag2   As channel 53       "    "    "
56   S/C STATUS     bit   significance
                    0 LSB LIU power ON
                    1     S/A plug status 0=Safe, 1=Arm
                    2     RUDAK-out (lock)
                    3     Mode-S Squelch open
                    4     ---
                    5     Memory Softerror Counter
                    6       "         "      "
                    7 MSB   "         "      "
57   ---
58   ---
59   ---
5A   ---
5B   N              no of 20ms per dot, morse speed.
5C   n              running count of units for morse.
5D   ---
```

```
5E   TRANSPONDER    bit   significance  (OUT7)
                    0 LSB GB OFF
                    1     GB FSK (1=+170Hz)
                    2     DPSK OFF
                    3     EB ON
                    4     --+ PSK source
                    5     -+! for GB (EB: don't care)
                           !!
                           00 - no PSK
                           01 - ranging
                           10 - EB source
                    6     Low power transponder ON
                    7 MSB Passband OFF (Beacons and Mode-J +3dB)
5F   ---
60   MODUS          bit   significance  (magnet control)
                    0     magnet system ON
                    1     undespun magnet
61   M-Soll         magnet vector desired angle to the despun sun
                    (clockwise as seen from top, 1 circle = 256)
62   M-Out          bit   significance  (OUT3, also L,S,J control)
                    0 LSB polarity Arm 1
                    1     polarity Arm 2
                    2     polarity Arm 3
                    3     Magnet power ON
                    4     Mode-J ON
                    5     ---
                    6     Mode-S ON
                    7 MSB Mode-L ON
63   O-FRAC-lo      Fractional Z increment in 20ms
64   O-FRAC-hi                       Counts down to 0 from preset
                                     value. 255th Z has different
                                     value of O-FRAC. ~7000 counts/Z.
65   O/256          Z from perigee
66   O#-lo          Orbit number
67   O#-hi
68   UHR            10ms             UTC
69                  sec
6A                  min
6B                  hour
6C                  day              1st January 1978 = AMSAT day 0.
6D                  256day
6E   SU0            10ms             IPS stopwatch 0.
6F                  sec
70                  min
71                  min*256
72   SU1            10ms             IPS stopwatch 1.
73                  sec
74                  min
75                  min*256
76   SU2            10ms             IPS stopwatch 2.
77                  sec
78                  min
79                  min*256
7A   SU3            10ms             IPS stopwatch 3.
7B                  sec
7C                  min
7D                  min*256
7E   Event-Lo                        Used as event ID word in
7F   Event-Hi                        intermediate buffer.
```

October 12, 1990

UO-14



Names:	UoSAT-D, UoSAT-3
Object #:	20437
International ID:	1990-005B
Launch:	22 JAN 1990
Period:	100.8 minutes
Increment:	25.2° W
Orbit:	LEO
Altitude:	perigee 780 km apogee 804 km
Modulation type(s):	9600 bps FSK AX.25 1200 bps AFSK (seldom on)
Downlink:	435.070 MHz

Sponsoring organization: University of Surrey

Telemetry equipment:

pointable 435 MHz antenna with preamp,
modified 435 MHz FM receiver, 9600 bps FSK modem, TNC, computer or
435 MHz FM receiver, 1200 bps FSK demodulator, computer

Software: DTLM by K8KA from AMSAT-UK

This satellite's mission is to support:

1) Amateur Radio packet communications using low Earth orbit satellites and the advancement of store-and-forward communications technology,
2) studies of the orbital, radiation environment and its effects on semiconductors,
3) in-orbit demonstration and evaluation of novel spacecraft technologies,
4) refinement of low-cost computer controlled spacecraft attitude determination and control systems providing precision Earth pointing.

The UoSATs are in a sun synchronous orbit and appear over each location on earth 2-3 passes in the morning and in the evening.

Currently I do not have the 9600 bps equipment to receive UO-14 telemetry, so I have included a description by Jeff Ward. This is found on CIS HAMNET as PCETLM.DOC. The 1200 bps telemetry is seldom on and is to use the same packet format as UO-11. This description is found in section 3.

Posted: Wed, May 2, 1990 4:06 AM PST Msg: BGJA-4244-6234
From: UOSAT
To: DOCS
Subj: UO-14 PCE TELEMETRY FORMAT

UoSAT-OSCAR-14 PACSAT Communications Experiment Telemetry Format

Telemetry is used to monitor the state of experiments and housekeeping subsystems onboard the satellite. In particular, it measures voltages, currents, temperatures and the status of digital switches.

The PCE transmits telemetry in AX.25 UI frames at 9600 bps. A "packet" of telemetry is wholly contained in the information field of a single UI frame. Each packet contains a timestamp indicating when the samples were taken, the the data samples (including additional information detailed below), and a CRC. The CRC is provided because the link between the KISS TNC used to receive the UI frames and the computer used to display or analyze the telemetry may become unreliable at high data rates. Thus the telemetry packet format is:

<timestamp> <data> [<data>...] <crc>

All of this is contained WITHIN the AX.25 UI frame information field. The information field will not exceed 256 bytes in length.

In addition to the fields contained in the telemetry packet, the receiving process must maintain a <channel> variable. The use of this variable becomes clear below.

Interpretation of the fields is as follows:

BYTE ORDER

All multi-byte values are stored least significant byte first. Where bits are numbered, bit 0 is the least significant bit of a byte or multi-byte value.

TIMESTAMP

The <timestamp> is a 4-byte, unsigned integer representing the number of seconds since 0000 UTC January 1, 1970. This is the UNIX standard time, and is also the format for times under the draft ANSI C standard.

DATA

Each <data> item is a 2-byte, unsigned integer, with internal encoding as follows:

bits 0 - 11	A 12-bit <value> field
bits 12 - 15	A 4-bit <type> field

The <type> field tells the receiver how to interpret the <value> field, and what other action to take. The following <type> items are defined:

bit				
15	14	13	12	Interpretation and Action
0	0	1	0	<value> is a channel number. Initialize <channel> variable to <value>.
0	0	0	1	<value> is the telemetry sample for current <channel>. Do not increment <channel> after processing <value>.
0	0	0	0	<value> is the telemetry sample for current <channel>. Increment <channel> after processing <value>.

All other types are currently undefined and should be ignored.

The first <data> item in a telemetry packet will always be of type 0010, to initialize the channel variable.

CRC

The cyclic redundancy check is provided as protection against errors on the link between the receiving TNC and the computer which is processing the telemetry. It is the XMODEM CRC algorithm encoding all bytes, from the first byte of the <timestamp> to the last <data> byte.

ADDRESS and PID

We are currently transmitting these frames with an AX.25 Protocol Identification byte of 0xf0. The source address is UOSAT3-0 and the destination address is TLM-0.

EXPLAINATION and EXAMPLES

In the examples, assume that the <timestamp> is 2638d6ce hexidecimal. (From here on, hexidecimal numbers are indicated by a leading 0x.)

You will see that this packet format allows us to efficiently encode the most common type of telemetry "frame" - e.g. a frame in which we begin with channel 0 and increment through the channel numbers. In this case, the packet starts out with:

```
0x2638d6ce  /* timestamp                             */
0x2000      /* <type>=0010, <value>=0                */
            /* so set your channel variable to 0     */
```

and then proceeds with the data for each channel, with the <type> bits indicating "increment" (0000). For example, if channel 0 is at a value of 0x496 and channel 1 is at 0x003, we have

```
0x2638d6ce  /* timestamp                                  */
0x2000      /* set your channel variable to 0             */
0x0496      /* value of channel 0 and increment channel to 1*/
0x0003      /* value of channel 1 and increment channel to 2*/
```

Etc.

However, on UO-14 (as on UO-11) we have some "submultiplexed channels". The primary example is channel number 15 which; every 12 times it is read it returns voltages for the 10 cells of the battery and two 0 values for synchronization. Ideally we would have the PCE read the channel 12 times for each telemetry packet and transmit all 12 values. This is why the "display but don't increment" <type> (0001) is defined. So, now, in our frame we have

```
0x2000      /* set your channel variable to 0               */
0x0496      /* value of channel (0) and increment channel to 1   */
0x0001      /* value of channel (1) and increment channel to 2   */
 ...        /* 13 other <data> items with "increment" type.      */
 ...        /* leaving the channel variable at 15                */
0x10nn      /* first submultiplexed battery cell sample          */
0x10nn      /* second submultiplexed battery cell sample         */
 ...        /* and so on, until the last of the 12 samples,      */
0x00nn      /* which is of "increment type.                      */
```

We can also "jump over" any unwanted channels in the frame by inserting another "set your channel variable" data entry. This is done on UO-14 to skip the blank channels between analog telemetry and digital status points.

So we have a flexible and efficient encoding system which does not require the transmission of every channel number, yet permits submultiplexing and channel number jumping. In the case of UO-14, where the native telemetry samples are 12-bits, we have "wasted" only 4 bits per channel on supervisory information to arrive at this flexibility.

UO-14 SAMPLE FRAME

A hex dump of the data in a telemetry packet from the UO-14 engineering model is reproduced below. It includes use of all features: 3 "set channel variable" entries (one at the beginning of the frame and 2 to jump over unwanted channels), 12 consecutive samples of channel 15 and 56 other samples. The CRC is also correct.

Figure 5-1 UO-14 sample telemetry frame

```
      CE D6 38 26 00 20 00 00 16 02 37 00 07 00
CF 01 CF 01 CF 01 08 02 00 00 49 02 CB 00 2A 00
CF 01 CF 01 F4 01 33 12 32 12 30 12 2B 12 29 12
27 12 22 12 24 12 00 10 00 10 3A 12 34 02 00 00
6D 00 81 02 34 00 CF 01 CF 01 C8 01 81 01 54 01
2C 00 C7 01 04 03 CF 01 CF 01 CF 01 E6 01 B0 00
03 01 36 01 5D 01 6A 01 A1 01 CB 01 28 20 00 00
00 00 00 00 00 00 8F 01 FB 01 10 02 55 02 DD 00
40 20 80 00 00 08 02 00 80 00 12 08 83 00 10 04
08 08 00 08 AB A8
```

CONCLUSION

Your comments are solicited - especially relating to any errors in this document. Address them to

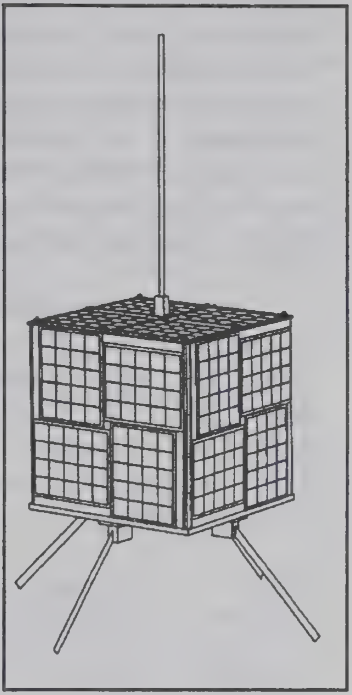
Packet: G0K8KA @ GB3UP
Telemail: UOSAT
Other nets: ELE001@UK.AC.SURREY.SYSD

or, last resort
Jeff Ward, G0/K8KA
UoSAT Unit
University of Surrey
Guildford, Surrey GU2 5XH
United Kingdom

Comments may also be forwarded via CIS by NK6K 71635,1174

March 5, 1991

AO-16



Name(s): PACSAT, Microsat
Object #: 20439
International ID: 1990-005D
Launch: 22 JAN 1990
Period: 100.8 minutes
Increment: 25.2° West
Orbit: LEO
Altitude: perigee 780 km
apogee 804 km

Modulation type(s): 1200 bps PSK AX.25

Sponsoring organization: AMSAT-NA

Downlink: 437.025 MHz(primary) SSB PSK
437.050 MHz(secondary) SSB PSK

Telemetry equipment:
pointable 437 MHz antenna with preamp,
437 MHz SSB receiver with external frequency
up/down control, 1200 bps PSK modem, TNC, computer

Software: TLMDCT.ZIP capture/decode from AMSAT-NA or CIS HAMNET
PBREL.ZIP capture from CIS HAMNET

This satellite's mission is to demonstrate Radio Amateur commitment to extending digital communications facilities; provide an easily utilized satellite based facility for data storage and forwarding using Amateur packet radio techniques. Research and experimentation with specialized protocols for efficient access and utilization of digital data satellites.

The Microsats are in a sun-synchronous orbit and appear over each location on earth 2-3 passes in the morning and 2 - 3 passes in the evening. This is normally between 9 am to noon and 8 pm to midnight in the southeastern United States.

This microsat requires the same ground station equipment as FO-12 and FO-20, so it is not always necessary to get new equipment. Figure 6.4 has a block diagram of the order in which to connect the equipment. Since both the capturing and the decoding of the telemetry is done with Bob McGwier's TLMDC software, let's look at the telemetry format first.

AO-16 telemetry format

For the first few months after deployment all of the Microsats transmitted telemetry using a 7-bit ASCII AX.25 format. During the spring of 1990 the Microsat engineering team switched the telemetry on AO-16, WO-18 and LO-19 to an 8-bit hexadecimal format. Essentially this means that you can no longer directly read the data on your terminal screen or directly print the data. If you attempt to use a terminal/printer to display the raw telemetry, you will get font changes, bells, form feeds and assorted maladies. The changes have been implemented to effect a much faster transfer of data. Only a change in the software program used to capture and decode the data was necessary. Because telemetry shares the downlink frequency and transmitter with the main mission of the microsats, it is only sensible to make the telemetry transmission as efficient as possible. The telemetry complexity has increased as a result of making the telemetry more efficient. These changes have been done in an orderly fashion, testing the changes and correcting problems before the next major change. Executable files for the IBM class of computers are available for capturing and decoding the telemetry soon after the changes are implemented. More changes may follow, but the basic telemetry format should be discernable throughout the changes.

The original microsat telemetry format was essentially the same format that DOVE uses today except AO-16 telemetry uses PSK modulation on SSB where DOVE uses AFSK on FM. The original microsat telemetry format is shown in Figure 6.1. The data from the TNC was in plain ASCII. The telemetry channel data was identified by the TLM address field and sent in AX.25 packets. Each channel was identified and separated from its data by a colon. This was quite easy to read with a standard terminal or terminal emulator program running on any computer.

Figure 6.1 Original version of AO-16 (PACSAT) telemetry frame during the final test at Kourou

```
PACSAT-1>TIME-1:PHT: uptime is 000/00:02:50  Time is Mon Dec 11 10:30:34 1989

PACSAT-1>TLM:00:FF 01:93 02:FF 03:75 04:FF 05:9D 06:82 07:7F 08:68 09:8E 0A:A4
0B:9A 0C:E8 0D:DB OE:00 0F:30 10:DA 11:82 12:00 13:54 14:7E 15:7C
16:81 17:7A 18:7D 19:7A 1A:7D 1B:7B 1C:7A 1D:7A 1E:28 1F:5C 20:8B

PACSAT-1>TLM:21:7B 22:74 23:24 24:21 25:29 26:00 27:00 28:00 29:00 2A:00 2B:00
2C:00 2D:26 2E:00 2F:7C 30:7B 31:7B 32:3E 33:00 34:7D 35:7D 36:7D
37:7D 38:7D 39:9D 3A:01

PACSAT-1>STATUS: 00 00 00 80 B0 18 55 02 00 80 00 00 B0 00 00 00 00 00 00 00

PACSAT-1>WASH:wash addr:26c0:0000, edac=0xac
```

The spring of 1990 saw the first change toward a more efficient telemetry format. This change was made to prepare for the PBBS operation. Figure 6.2 has an example of this version of telemetry. Whole Orbit Data(WOD) was also added to assist the command stations in monitoring the satellite. The most noticeable part of this change was that much of the data was sent as 8-bit hexadecimal values rather than 7-bit ASCII. This meant that it was also necessary to put your TNC into KISS mode, which essentially passes all of the data demodulated by the TNC directly to the computer. The software in the computer decides how to process the raw hexadecimal data it has received. The TLMDC software was updated in April 1990 to accommodate this change. Those ground stations attempting to capture the data using a standard terminal or emulator run into quite a problem. Most terminal programs don't store all the control codes, so even if it appears that the data was being logged correctly it isn't. Some lines and messages would be in ASCII and display correctly, but a number of graphics characters appeared on the screen. The cause of these graphic characters is hexadecimal data that corresponds to ASCII control codes. The telemetry channel identification and channel data were now sent for all 3Ch (61) channels in one packet. The 8-bit hexadecimal characters for the channel ID and channel data were now sent as 1 byte each. The original mode required two ASCII bytes for the channel and two for the data each plus a colon separator. So the telemetry went from 5 bytes/channel to 2 bytes/channel. The STATUS, LSTAT and BCRXMT data values were also changed to the hexadecimal format. Since I cannot directly print hexadecimal characters on paper, each hexadecimal value sent is written on the page as two ASCII characters. This is called a hex dump. I have also added spaces and <CR><LF>s to make the data more readable. Remember that this data comes down as a hexadecimal data stream. Since ASCII is a subset of hexadecimal data, message and digi data would display in a readable format, but the non-ASCII and control characters would cause your monitor or printer to behave erratically. TIME, TLM, STATUS, WOD, message, BCRXMT, LSTAT, and WASH data examples are included in Figure 6.2.

* *

Figure 6.2 AO-16 (PACSAT) telemetry data before PBBS active

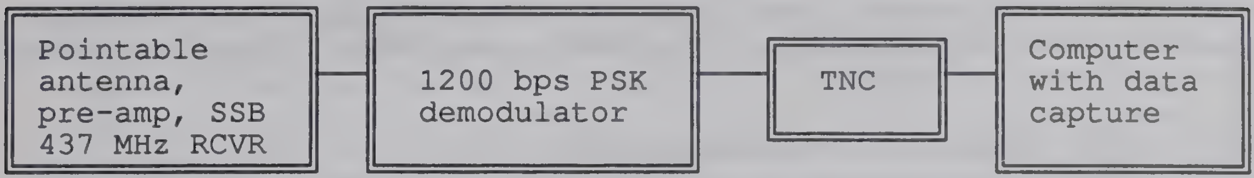
```
PACSAT-1>TIME-1:PHT: uptime is 043/23:21:04.  Time is Fri Oct 05 02:50:35 1990

PACSAT-1>TLM:6b570c27
0064 0194 0270 0376 0470 0597 0670 0767 0870 0990 0aa3 0b9c 0ce7 0ddc 0e00 0f31
10d5 1181 1201 1302 14b4 159c 168c 1788 1883 1983 1a83 1b84 1c86 1d82 1e25 1f5c
209c 217e 2217 233f 2431 2526 2600 2700 2800 2900 2a00 2b00 2c00 2d2a 2e00 2fa2
30a2 31a3 328a 3303 34b0 35b0 36ca 37a8 38bc 39d0 3a01

PACSAT-1>STATUS:6b570c27 8000001eb018aa020080000090b3c05cc000000

PACSAT-1>WOD:77ef08279007a5c3acd681ef08279010a4c4b0d58bef0827900ca3c4aad695
ef0827900aa4c2acd49fef08278f10a4bfadd6a9ef08279006a4bdb0d5b3ef08279000a4bb
b0debdef08279000a4beacbdc7ef08279000a4beabdcd1ef08279105a4bdaadddbef082791
069fbeaadfe5ef08279006a5bdabd9efef08279002a4baaadff9ef08279000a4b7aadb03f0
08279001a3b8aadb0df008279000a4b7abdb17f008279000a4b9aadf21f008279003a4baaa
dd2bf008279004a4b7abdd35f008279004a4b5aae23ff008279001a4b5aae249f008278d00
a4b4ace153f008279000a4b4aadf5df008278e00a4b4a9e267f008279002a4b4aae0

PACSAT-1>WOD:
   ... (data omitted, it is similar to the WOD data in the previous packet)

PACSAT-1>AMSAT:
10/3/90 0450Z:Dumping WOD to correlate
TX power amp temp with power output,
Ch: 32, 2A, 37, 36, 34, 1E.  Dump will end
about 10/5/90.  See you all in Houston?   73, WD0E


PACSAT-1>BCRXMT:vmax=749416 battop=753664 temp=198465

PACSAT-1>LSTAT:IP:0x3239 o:0 1:3809 f:5168, D:1

PACSAT-1>WASH:wash addr:3500:0000, edac=0x21
```

The store and forward BBS is now in place aboard PACSAT, so transmitter time is at a premium. All the data is a bit more cryptic than in the initial versions. The PBBS operation and file data contain hexadecimal data. The TLMDC program can still be used to capture and decode the telemetry. Figure 6.3 shows example data after the PBBS became operational. Remember that these transmissions use AX.25 protocol. This explains the extra hexadecimal characters associated with the packets. For more explanation read the AX.25 specification available from the ARRL. I am displaying this hex data stream with each non-ASCII byte represented as two ASCII numbers. The readable ASCII data is shown directly, and numerous space and <CR><LF> characters have been inserted for clarity. In the TLM data the channel identification is followed by the channel data for channels 00 - 3Ch. The microsat software is very versatile and can be changed to support systems under investigation. If new software is necessary, it will be available from AMSAT-NA and on the CIS and DRIG BBS. You should notice that their has been very little change to the telemetry. The major difference is the great amount of bulletin board data being transmitted. The WOD is no longer transmitted as telemetry, but as a bulletin board file. If you are interested in examining the hexadecimal data coming down use the TRACE ON command on your TNC. You will get all the hexadecimal data that comes down, the shifted-ASCII, and ASCII data displayed on the screen. Appendix D has a more complete example of received data using this TRACE ON feature.

Figure 6.3 PACSAT data format after PBBS active

```
PACSAT-12>BBSTAT:FULL A   : WB9ANQ K8TL   WB1HBU N8AM

PACSAT-12>WB9ANQ:
FD00AA550100044C0C0000020008323763633537653103000320202004000466
0700000500040AFDCB27060004D364CC271200044358CC270700010008000100
090002D9440A00029F1E0B0002AC001000046B7A31621100064B5A3142202013
000101140006776239616E711500062020202020201600040000000017000443
9ED127180001001900010226000962727563652E7A6970220006657463657463
23000870672C7265706C79000000504B03040A000000600936C5B161DB1702A
4E060000F20A000005000000425255434500D020112231415363768899ADB3C05
06121344C5F696F791A60529546EDDB1655DBA74D950214810C14F156D58B7

PACSAT-1>TIME-1:PHT: uptime is 035/20:20:49.  Time is Thu Feb 28 02:47:39 1991

PACSAT-1>AMSAT:2-26-91

AO-16 is in Experimentor Mode until about 0500Z on
2-28-91.  The raised COSINE transmitter is on (437.050),
and the S-band transmitter is on.  Please send reports
on the ease of copy of these transmitters to WB9ANQ or
WD0E.  73, WD0E

PACSAT-1>STATUS:4B6FCC278000001EB0187701000000006083C0500FB0000

PACSAT-12>BBSTAT:FULL A   : WB9ANQ K8TL   WB1HBU N8AM

PACSAT-1>LSTAT:I P:0x15CD o:0 l:1558 f:1558, d:1 st:5

PACSAT-1>TIME-1:PHT: uptime is 035/20:21:49.  Time is Thu Feb 28 02:48:39 1991

PACSAT-1>TLM:876FCC27
005E 0195 0256 0365 0469 0591 066A 0768 086C 0990 0AA2 0B9A 0CE8 0DDB 0E01 0F31
10D3 1181 1200 1302 14A9 1591 1694 178A 188A 1983 1A87 1B87 1C87 1D88 1E24 1F5C
209E 2179 2219 2350 2436 2563 2600 2701 2801 2900 2A00 2B00 2C00 2D4D 2E02 2F99
3098 3199 3200 331C 34AD 35AA 36C5 37AA 38B3 3984 3AE6
```

Figure 6.4 Block diagram of an AO-16 telemetry receiving station


Pointable antenna, pre-amp, SSB 437 MHz RCVR
1200 bps PSK demodulator
TNC
Computer with data capture

Capturing the telemetry

Setup a receiving station using the example in Figure 6.4. As the Microsat comes above the horizon, tune to get the strongest beacon signal. Then watching the PSK unit re-tune to get both a TUNE and LOCK indication on the PSK demodulator. It is a full time job to manually keep the PSK unit tuned and locked with the satellite signal. It is almost mandatory to have the PSK unit control the receiver frequency. Receiving telemetry from horizon to horizon requires a pointable antenna. The signal above 10-15 degrees elevation may be strong enough to receive on a stationary antenna, you decide how much of the telemetry you want to capture. The satellite moves rapidly, so it is necessary to track the satellite closely to maintain a good signal strength.

TAPR 1200 bps PSK modem switch settings:

MAN	means Manchester, not manual
USB/LSB	set the same as the receiver sideband selected
PSK ON	
JOINT/SPLIT	this doesn't matter for telemetry reception

TNC-2 settings/commands:
PARITY 0
AWLEN 8
KISS ON
RESTART

N.B. Remember to command KISS OFF in the TNC before turning the TNC power off.

Software to capture PACSAT telemetry

Two programs are currently available for the IBM computers to capture the hexadecimal telemetry from PACSAT. TLMDC by Bob McGwier has been around and still works well, even though the downlink data has changed. The PB.EXE program by Jeff Ward can also be used to capture files transmitted in the PACSAT BROADCAST PROTOCOL FORMAT. Simply run the PB program and activate the KISS LOG ON item. The filename for the received data is automatically generated from the date the data is received and have a .KSS extension.

An alternate method of data capture is to use a terminal program that will store binary data. Few terminal programs will do this and it requires quite a robust test to determine whether your terminal program will work correctly. I have found 2 versions of PC-TALK to capture binary data correctly. Make sure that <CR>s are not changed to <CR><LF>, or any other control characters filtered or changed. ProComm will store everything except the 00 <NULL> character in the DOWNLOAD mode, but even fewer control characters in the LOG

TO FILE mode. The fact that ProComm won't store all the characters makes it unusable for data capture. Attempts to print or display hex data will result in erratic behavior of your printer or nonsense screens. A utility program what can display stored hexadecimal data as ASCII characters is necessary if you wish to look at the data. Debug, Norton Utilities, and (under Windows 3.0) BROWSER and IL (available on most BBS) will display both the hex and ASCII data to the screen.

Using the TLMDC software to capture telemetry

To capture the telemetry using the TLMDC software, it is necessary to have the TNC, the computer and TLMDC program configured with the same serial parameters. The default values for TLMDC are COM1:9600,N,8,1 operation. To configure the TNC set the baud rate dip switches, and use the AWLEN and PARITY settings referenced above. TLMDC software must have the 8 data bits and NO parity configuration. The IBM configuration is:

```
C:>mode COM1:9600,N,8,1 <CR or ENTER>
```

If you wish to run the TLMDC software at a different baud rate, this can be done by adding a serial configuration argument to the TLMDC execution command. COM1 and N,8,1 must be used however. Make sure that the TNC, computer and TLMDC program all are using the same serial parameters! Limited success will occur if a baud rate below 2400 is selected.

```
C:>mode COM1:4800,N,8,1 <CR or ENTER>
C:>TLMDC COM1:4800,N,8,1 <CR or ENTER>
```

To decode the telemetry it is necessary to have the four files PACSAT, DOVE, WEBER, and LUSAT are in the same directory as TLMDC. These files contain the calibration equations, no equations = no decoding. Currently DOVE is still in a straight ASCII format and telemetry cannot be decoded using TLMDC v4/10/90, only the microsats using the hexadecimal telemetry data. The telemetry data and the ASCII portion of the PBBS data appear readable on the screen when the TLMDC is run. Again since the TLM, STATUS, and LSTAT data are in hexadecimal you may get graphics characters in place of actual data displayed on the screen.

Select "D" to DUMP the data to a file as it is received or
"T" realtime decoding of the telemetry.

The "D" option will prompt for a "RAW" file and an "ASCII" file. Select descriptive filenames that describe the satellite, orbit number, date, or some combination of the three. "DUMP" will appear in the lower right hand corner, telling you the program is currently in DUMP mode and capable of logging data to a file as it comes in. All of the hexadecimal data is stored in the raw file and can be recalled for later decoding. Valid ASCII data will print to the screen. Pressing the "D" key again will terminate the data storage function, but keep data printing to the screen. You may display or print the data stored in the ASC file.

Decoding telemetry on the microsats

The microsats are new and experimental spacecraft, so what is true today is not necessarily true tomorrow. Take note that the telemetry channels and format are all changeable. Since most of the data is in hexadecimal format it is almost mandatory to use a dedicated program to decode Microsat telemetry. If you must hand decode some channels, you need to look at the data using a program that will display the hexadecimal data. Get the data from the selected channel, convert it to decimal, and substitute it into the correct calibration equation.

See the examples of hand decoding in the chapter on DO-17 (DOVE). Survey data shows that approximately 50% of the people operating on the satellites use IBM based machines. So for now the software will be available first for these machines. Joe Kasser is working on an addition to his WHATS-UP program to decode the binary data from the microsats. He has developed telemetry format conversion routines that allow decoding of most of the telemetry from most of the amateur satellites using one decoding program. When the microsat format stabilizes there will be a version of WHATS-UP that will decode DOVE, FO-20, UO-11, AO-13 and the microsats. Today we have software provided by Bob McGwier to decode telemetry from the microsats. TLMDCT.ZIP is available from AMSAT-NA and CIS HAMNET. Make sure that you have the PKUNZIP.EXE file to 'unzip' Bob's program.

Decoding using the TLMDC software

Software decoding of the hexadecimal microsat telemetry is most commonly done using the TLMDC.EXE program. Start the TLMDC program just as described in the section on capturing telemetry using TLMDC. To decode telemetry during reception, simply press the "T" key. This will initiate a screen display of the next received telemetry block. This screen is updated as each new TLM frame is received. Pressing any key will stop the realtime telemetry decoding and return you to the incoming data display screen. Figure 6.5 has a sample of the screen output after selecting the 'T' (telemetry) menu selection. If you wish to review some old telemetry data, you must have a file that stored the data while the TNC was in KISS mode. Both the TLMDC.EXE and the PB.EXE programs produce files of the correct type. With TLMDC running select the "F" option. This option prompts you to enter the filename which contains the data that you wish to decode. The first telemetry frame it finds in the selected file is then displayed on the screen. Pressing the <SPACE BAR> will display the next telemetry frame. When no more telemetry data is found, pressing the <SPACE BAR> again will return you to the main menu. You will need to know the exact filename when you enter the program, there is no provision to get a list of filenames in the current directory while the program is running.

Figure 6.5 Sample TLMDC telemetry screen output using data from Figure 6.2

```
uptime is 000/11:09:31.  Time is Wed Nov 28 04:11:11 1990           PACSAT
Rx D DISC        1.471 k  Rx D S meter   150.000 C  Rx C DISC       -1.211 k
Rx C S meter   116.000 C  Rx B DISC       -0.238 k  Rx B S meter   151.000 C
Rx A DISC       -0.645 k  Rx A S meter   105.000 C  Rx E/F DISC     -0.283 k
Rx E/F S meter 144.000 C  +5 Volt Bus      5.002 V  +5V Rx Current   0.039 A
+2.5V  VREF      2.495 V  8.5V BUS         8.602 V  IR Detector      0.000 C
LO Monitor I     0.002 A  +10V Bus        10.800 V  GASFET Bias I    0.003 A
Ground REF       0.000 V  +Z Array V       0.205 V  Rx Temp          4.234 D
+X (RX) temp    16.336 D  Bat 1 V          1.324 V  Bat 2 V          1.332 V
Bat 3 V          1.337 V  Bat 4 V          1.326 V  Bat 5 V          1.331 V
Bat 6 V          1.412 V  Bat 7 V          1.340 V  Bat 8 V          1.339 V
Array V         10.635 V  +5V Bus          4.905 V  +8.5V Bus        8.261 V
+10V Bus        10.950 V  BCR Set Point   22.062 C  BCR Load Cur     0.428 A
+8.5V Bus Cur    0.045 A  +5V Bus Cur      0.186 A  -X Array Cur    -0.010 A
+X Array Cur    -0.021 A  -Y Array Cur    -0.022 A  +Y Array Cur    -0.018 A
-Z Array Cur    -0.022 A  +Z Array Cur    -0.020 A  Ext Power Cur   -0.020 A
BCR Input Cur    0.126 A  BCR Output Cur   0.012 A  Bat 1 Temp       6.654 D
Bat 2 Temp       7.260 D  Baseplt Temp     6.654 D  PSK TX RF Out    2.152 W
RC PSK TX Out    0.007 W  PSK TX HPA Tem   0.603 D  +Y Array Temp    1.814 D
RC PSK HPA Tem -13.919 D  RC PSK BP Temp   6.654 D  +Z Array Temp    1.209 D
S band TX Out    0.866 W  S band HPA Tem   1.000 C

        Total Array C= 0.000 Bat Ch Cur=-0.416 Ifb= 0.126 I+10V= 0.302
TXA:1 TXB:0 TX Pwr:A SbT:0 BCR:1E SCR:5 LP:9 HI:B BT:3C WC: 0space to continue
```

Decoding the STATUS data line

```
PACSAT-1>STATUS:4B6FCC278000001EB01877010000000006083C0500FB0000
```

The meaning and order of each byte in the status line is still changing. So to avoid confusion it is not decoded here, but will be decoded in a later edition of this handbook.

Decoding the TIME-1 data line

```
PACSAT-1>TIME-1:PHT: uptime is 043/23:21:04.  Time is Fri Oct 05 02:50:35 1990
```

The time line on the microsats identifies the satellite, gives the current UTC day and time. Uptime is the decimal number of days, hours, minutes and seconds that the current software has been running.

Decoding the LSTAT data line

```
PACSAT-1>LSTAT:I P:0x15CD o:0 l:1558 f:1558, d:1 st:5
```

LSTAT stands for Load Status. It describes the status of software uploading. This could be either a new operating system (the command and control software for the satellite operation) or task (specific function for the satellite). Following the LSTAT:

I/A	I for Inactive load status or A for Active upload in progress.
P:0x	4 digit hexadecimal address for the last program/task started
o:	overflow; decimal number of bytes in the AX.25 downlink buffer that were lost (thrown away) because the output buffer was full
l:	left, amount of contiguous edac memory remaining (decimal number)
f:	free, total amount of free memory; equal to or greater than the 'l' value previously defined (decimal number)
d:	digipeater status, 1 = active, 0 = OFF
st:	refers to the last task started

Decoding the BBSTAT data line

```
PACSAT-12>BBSTAT:FULL A   : WB9ANQ K8TL   WB1HBU N8AM
```

This line is part of the bulletin board system and tells which uplink channels are active and the stations that are connected.

Decoding the BCRXMT data line

```
PACSAT-1>BCRXMT:vmax=749416 battop=753664 temp=198465
```

The BCRXMT line provides information on the charging rate of the batteries relative to their temperature. Divide the values by 65536. Battop is a fixed setpoint, vmax is calculated depending upon the temperature of the batteries.

Decoding the WASH data line

```
PACSAT-1>WASH:wash addr:2f80:0000, edac=0xab
```

WASH refers to cleaning out the SEUs (single event upset, memory error) from the edac (error detecting and correcting) memory. The address is the current location of the operating system while it is looping through memory correcting the errors. The number following edac is the total number of errors found. The WASH data has now been incorporated into the STATUS line.

Microsat WOD

The microsats began sending WOD in the summer of 1990. Since the PBBS has become operational WOD is no longer sent as directly addressed packet frames. It is stored as a file and downlinked as a file as requested. This description is for historical purposes and to give some insight into microsat WOD format. Each AX.25 packet of WOD was 8-bit hexadecimal with packet address of WOD-1. Figure 6.6 contains a sample of this WOD data, Appendix D contains a longer listing. The first 4 bytes are the timestamp. The time format is the number of seconds elapsed since JAN 1, 1970. This is sometimes called UNIX time and familiar to IBM "C" programmers. The time is sent least significant byte first. The data follows the time, one byte per channel. Another packet frame was necessary to identify the channels sampled. Figure 6.6 has 2 examples of a frame identifying the WOD channels. The AMSAT message frame and WODCH frame. I have inserted spaces and <CR><LF> in appropriate places to make the data more readable.

Channel 32 is PSK TX RF out
Channel 2A is -Z array current
Channel 37 is Raised Cosine PSK baseplate temperature
Channel 36 is Raised Cosine PSK high power amp temperature
Channel 34 is PSK TX high power amp temperature
Channel 1E is the array voltage

Figure 6.6 sample AO-16 (PACSAT) WOD

```
PACSAT-1>WODCH
32 2A 37 36 34 1E

PACSAT-1>AMSAT:
10/3/90 0450Z:Dumping WOD to correlate
TX power amp temp with power output,
Ch: 32, 2A, 37, 36, 34, 1E.  Dump will end
about 10/5/90.  See you all in Houston?   73, WD0E

PACSAT-1>TIME-1:PHT: uptime is 043/23:20:54.  Time is Fri Oct 05 02:50:25 1990

PACSAT-1>WOD
83ed0827 87 00 a4 d0 b0 24
8ded0827 87 01 a4 d0 ac 24
97ed0827 87 00 a4 cc b0 24
a1ed0827 89 00 a4 cc b0 24
abed0827 87 00 a4 cc ad 24
b5ed0827 87 00 a4 d0 b0 24
bfed0827 87 00 a4 d0 b0 24
c9ed0827 88 00 a4 cc b0 24
```

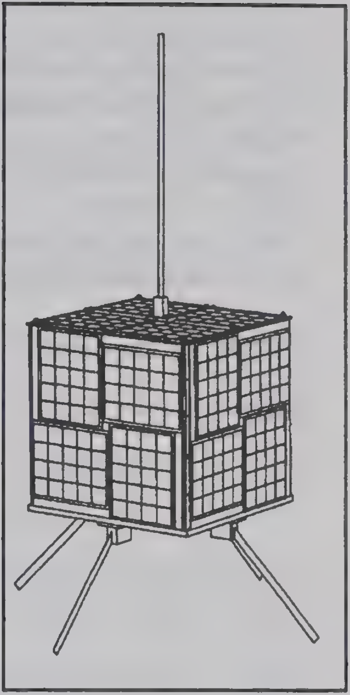
Table 6.1 PACSAT (AO-16) PSK telemetry calibration equations

Channel	Label	A	B	C	units
0	Rx D DISC:	+9.202	-0.08990	0.000	kHz
1	Rx D S meter:	+0.000	+1.000	0.000	Counts
2	Rx C DISC:	+9.179	-0.09277	0.000	kHz
3	Rx C S meter:	+0.000	+1.000	0.000	Counts
4	Rx B DISC:	+9.837	-0.08838	0.000	kHz
5	Rx B S meter:	+0.000	+1.000	0.000	Counts
6	Rx A DISC:	+9.779	-0.09144	0.000	kHz
7	Rx A S meter:	+0.000	+1.000	0.000	Counts
8	Rx E/F DISC:	+10.817	-0.09911	0.000	kHz
9	Rx E/F S meter:	+0.000	+1.000	0.000	Counts
A	+5 Volt Bus:	+0.000	+0.0305	0.000	Volts
B	+5V Rx Current:	+0.000	+0.000250	0.000	Amps
C	+2.5V VREF:	+0.000	+0.0108	0.000	Volts
D	8.5V BUS:	+0.000	+0.0391	0.000	Volts
E	IR Detector:	+0.000	+1.000	0.000	Counts
F	LO Monitor I:	+0.000	+0.000037	0.000	Amps
10	+10V Bus:	+0.000	+0.0500	0.000	Volts
11	GASFET Bias I:	+0.000	+0.000026	0.000	Amps
12	Ground REF:	+0.000	+0.0100	0.000	Volts
13	+Z Array V:	+0.000	+0.1023	0.000	Volts
14	Rx Temp:	+101.05	-0.6051	0.000	Deg. C
15	+X (RX) temp:	+101.05	-0.6051	0.000	Deg. C
16	Bat 1 V:	+1.8225	-0.0038046	0.000	Volts
17	Bat 2 V:	+1.9418	-0.0046890	0.000	Volts
18	Bat 3 V:	+1.8699	-0.0041641	0.000	Volts
19	Bat 4 V:	+1.7403	-0.0032880	0.000	Volts
1A	Bat 5 V:	+1.8792	-0.0042492	0.000	Volts
1B	Bat 6 V:	+2.0499	-0.0054532	0.000	Volts
1C	Bat 7 V:	+1.9062	-0.0045331	0.000	Volts
1D	Bat 8 V:	+1.7536	-0.0033192	0.000	Volts
1E	Array V:	+8.055	+0.06790	0.000	Volts
1F	+5V Bus:	+2.035	+0.0312	0.000	Volts
20	+8.5V Bus:	+5.464	+0.0184	0.000	Volts
21	+10V Bus:	+7.650	+0.0250	0.000	Volts
22	BCR Set Point:	-6.1130	+1.1270	0.000	Counts
23	BCR Load Cur:	-0.0477	+0.00767	0.000	Amps
24	+8.5V Bus Cur:	-0.00179	+0.000894	0.000	Amps
25	+5V Bus Cur:	-0.00104	+0.00406	0.000	Amps
26	-X Array Cur:	-0.00995	+0.00243	0.000	Amps
27	+X Array Cur:	-0.02370	+0.00254	0.000	Amps
28	-Y Array Cur:	-0.02220	+0.00273	0.000	Amps
29	+Y Array Cur:	-0.01810	+0.00259	0.000	Amps
2A	-Z Array Cur:	-0.02230	+0.00221	0.000	Amps
2B	+Z Array Cur:	-0.02000	+0.00232	0.000	Amps
2C	Ext Power Cur:	-0.02000	+0.00250	0.000	Amps
2D	BCR Input Cur:	-0.02345	+0.00355	0.000	Amps
2E	BCR Output Cur:	+0.00869	+0.00303	0.000	Amps
2F	Bat 1 Temp:	+101.05	-0.6051	0.000	Deg. C
30	Bat 2 Temp:	+101.05	-0.6051	0.000	Deg. C
31	Baseplt Temp:	+101.05	-0.6051	0.000	Deg. C
32	PSK TX RF Out:	-0.0291	+0.00361	+0.0000869	Watts
33	RC PSK TX Out:	+0.0055	+0.00172	+0.0001180	Watts
34	PSK TX HPA Temp	+101.05	-0.6051	0.000	Deg. C
35	+Y Array Temp:	+101.05	-0.6051	0.000	Deg. C
36	RC PSK HPA Temp	+101.05	-0.6051	0.000	Deg. C
37	RC PSK BP Temp:	+101.05	-0.6051	0.000	Deg. C
38	+Z Array Temp:	+101.05	-0.6051	0.000	Deg. C
39	S band TX Out:	-0.0088	+0.00435	0.000	Watts
3A	S band HPA Temp	0.000	+1.000	0.000	Counts

Calibration equation: Y = A + X(B + (X*C)), where x is the channel data

March 5,1991

DO-17



Name(s): DOVE (Digital Orbiting Voice Encoder)
Object #: 20440
International ID: 1990-005E
Launch: 22 JAN 1990
Period: 100.8 minutes
Increment: 25.2° West
Orbit: LEO
Altitude: perigee 780 km
apogee 804 km

Transponder: N/A
Modulation type(s): 1200 bps AFSK AX.25 FM
DAC/Flash RAM voice reproduction,
SC-02 Digitized voice

Sponsoring organization: BRAMSAT (AMSAT-BRAZIL)

Downlink: 145.825 MHz FM

Telemetry equipment: almost any type of outdoor 2M antenna,
2M FM receiver, 1200 bps TNC, computer/terminal

Software: G3ZCZ.ZIP has WHATS-UP on CIS,
NK6K-TLM from AMSAT-NA or CIS HAMNET

DOVE's mission is to transmit a voice modulated beacon for educational and scientific purposes. "Language Art" messages composed and spoken by children from all around the world have been selected and will be uploaded about twice a week. These voice messages will alternate with the telemetry data. To get better voice quality the engineering team has decided to use the DAC and ram combination rather than the on-board SC-02 voice synthesis chip. The DOVE/DO-17 telemetry is sent at 1200 bps, AFSK modulation using AX.25 packets transmitting on 145.825 MHz FM. The data can be collected with a standard 2M FM receiver and a 1200 bps AFSK packet TNC (normal terrestrial packet). Nearly any terminal program can be used to display the data and store it to disk for later analysis.

DOVE telemetry format

Dove uses 59 (3Ah hexadecimal) telemetry channels to report the current condition of the satellite. An entire block of information contains TIME, TLM, LSTAT, STATUS and WASH information. The telemetry data has channel numbers and the channel data that are hexadecimal values (hex or base 16). This is done because the onboard microprocessor operates in hexadecimal and it is more efficient to transmit the data in hexadecimal than decimal/base 10.

Dove sends the 59 telemetry channels in 2 groups/packets. The first group is composed of channels 00 - 20h and the second group is 21h - 3Ah. from the satellite. Before voice transmissions start, the telemetry occurs every 10 to 20 seconds, so on a good pass you could receive about 75 sets of data. DOVE's telemetry is a very good one to use as an introduction to telemetry because it offers: 1) a classic, generalized telemetry format; 2) the data can be captured using readily available equipment; 3) it has a strong signal; and 4) it provides quite a bit of interesting data. Figures 7.1 and 7.3 each contain a sample DOVE telemetry frame. Figure 7.2 has examples of decoding the data. Table 7.1 lists the calibration equations necessary to decode the DOVE telemetry. The DOVE-1>TLM: packet address field identifies this as telemetry. The data contains the channel followed by the data value for that channel. Note that the hex channel number and the hex data are separated by a colon. The data needs to be calibrated using the general formula and the constants from Table 7.1.

Figure 7.1 sample DOVE telemetry.

```
DOVE-1>TIME-1:PHT: uptime is 001/01:10:22.  Time is Mon Jul 23 03:52:18 1990

DOVE-1>TLM:00:59 01:58 02:88 03:30 04:56 05:56 06:6F 07:49 08:6C 09:6A 0A:A2
0B:DC 0C:E8 0D:D6 0E:00 0F:24 10:C8 11:88 12:00 13:01 14:B5 15:A3
16:9B 17:9A 18:9C 19:9B 1A:98 1B:94 1C:A0 1D:9C 1E:21 1F:5D 20:BC

DOVE-1>TLM:21:8E 22:78 23:1C 24:1C 25:35 26:00 27:00 28:00 29:00 2A:00 2B:00
2C:00 2D:30 2E:00 2F:A4 30:D2 31:A4 32:06 33:28 34:CA 35:AA 36:B1
37:B0 38:BF 39:85 3A:87

DOVE-1>STATUS: 80 00 00 85 B0 18 55 02 00 30 00 00 09 0B 3C 05 29 5A 03 04
DOVE-1>LSTAT:I P:0x3000 o:0 l:13081 f:13081, d:0

DOVE-1>WASH:wash addr:3640:0000, edac=0x3f
```

Decoding DOVE Telemetry

The received telemetry channel data must be normalized using the calibration equation found in Table 7.1. Constants from the table for each channel plus the received data converted to decimal are substituted into a general equation to provide the actual data value. The general formula used to convert DOVE telemetry is :

$$Y = Cx{*}{*}2 + Bx + A \qquad \text{or} \qquad Y = A + X(\,B + (X*C)),$$

where A, B, & C are the calibration constants for each channel and X is the decimal data value received for that particular channel. This is a slightly different arrangement of the calibration constants than has previously been published. I changed them because a number of people I gave the original equations to substituted the constants incorrectly. First we will look at examples of hand decoding the telemetry then look at available software to do the decoding. The hand decoding example uses the DO-17 telemetry from Figure 7.1.

Begin by looking through the list of labels in Table 7.1 and select a channel that looks interesting. Find the data for the selected channel in the telemetry frame (Figure 7.1), convert the hexadecimal data value for the selected channel to decimal. Substitute the data value for X, and substitute the selected channel constants for A, B, & C in the general calibration equation. Finally solve the equation and append the descriptive label to complete the decoding of the selected channel.

The Microsats are a new class of satellites and may still undergo some changes in the telemetry format. Information on any changes will be available from any of the AMSAT nets, AMSAT bulletin boards, or from your Area Coordinator.

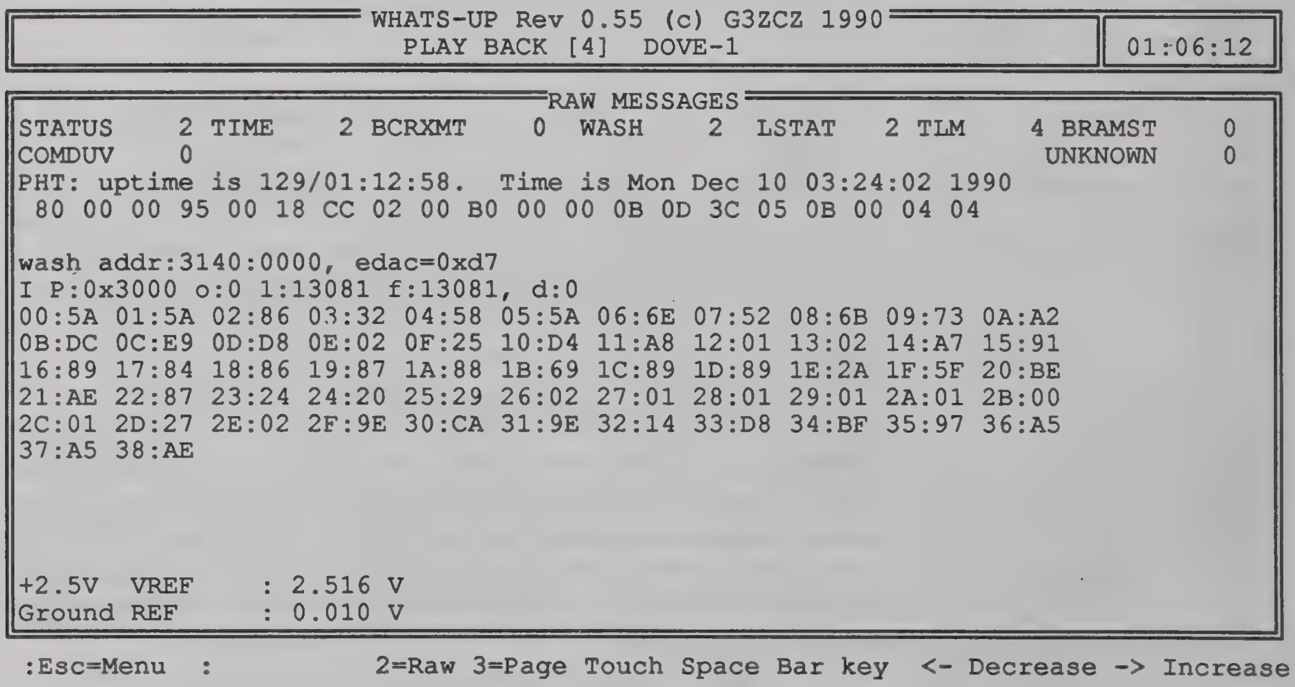
Figure 7.2 DOVE hand telemetry decoding examples.

```
channel 1Bh has a value of 7Fh (127 base 10),  solving using the general Dove
formula:
Y = 1.8381 + 127( -0.003845 + (127*0)) -> 1.8381 + ( -0.488315) -> 1.35 V
On Mon Jul 23 1990 03:52:18 UTC, the voltage of DOVE Battery #6 = 1.35 volts.

DOVE channel 35h has data value of AAh.
AAh -> Ah = 10 decimal, so 10 x 16 = 160   +  (Ah or 10) = 170 data value

channel  description         A            B            C            unit
35       +Y Array Temp   +101.05      -0.6051       0.000          Deg. C

Y = A + X( B + (X*C))
Y = 101.05 + 170( -.6051 + (170*0))
Y = 101.05 + 170( -.06051 + 0)
Y = 101.05 + ( -102.867 )
Y = -1.10 degrees C
The temperature of the +Y side panel was  -1.10 degrees C.

                ============================================

Channel       computed calibration equations

6      10.427 + 111( -0.09274 + (X * 0)) --> 0.1328 kHz receiver A DISC
7      0.0 + 73( 1.0 + X(0)) --> 73 counts on receiver A S meter
A      0.0 + 162(0.0305 + X(0)) --> +4.941 V on the +5 V Bus
B      0.0 + 220(0.000100 + X(0)) --> .022 A or 22 mA +5V receiver
13     0.0 + 1(0.1023 + X(0)) --> +0.1023 V on +Z array

16     1.7932 + 155( -0.0034084 + (X * 0)) --> 1.264 V on Battery #1
17     1.7978 + 154( -0.0035316 + (X * 0)) --> 1.253 V on Battery #2
18     1.8046 + 156( -0.0035723 + (X * 0)) --> 1.247 V on Battery #3
19     1.7782 + 155( -0.0034590 + (X * 0)) --> 1.242 V on Battery #4

26     -0.01075 + 0( +0.00215 + (X * 0)) --> -0.01075 mA from -X array
27     -0.01349 + 0( +0.00270 + (X * 0)) --> -0.01349 mA from +X array
28     -0.01196 + 0( +0.00239 + (X * 0)) --> -0.01196 mA from -Y array
29     -0.01141 + 0( +0.00228 + (X * 0)) --> -0.01141 mA from +Y array
2A     -0.01693 + 0( +0.00245 + (X * 0)) --> -0.01693 mA from -Z array
2B     -0.01137 + 0( +0.00228 + (X * 0)) --> -0.01137 mA from +Z array
no current from any of the solar panels, so the satellite is in eclipse

14     101.05 + 181( -0.6051 + (X * 0)) --> -8.473 Deg C receiver temperature
15     101.05 + 163( -0.6051 + (X * 0)) --> +2.418 Deg C (+X) receiver temp
2F     101.05 + 164( -0.6051 + (X * 0)) --> -1.81  Deg C battery #1 temperature
34     101.05 + 202( -0.6051 + (X * 0)) --> -21.18 Deg C PSK TX HPA temperature
35     101.05 + 170( -0.6051 + (X * 0)) --> -1.81 Deg C +Y array temperature
38     101.05 + 191( -0.6051 + (X * 0)) --> -14.5 Deg C +Z array temperature
```

Telemetry Decoding Software for DOVE

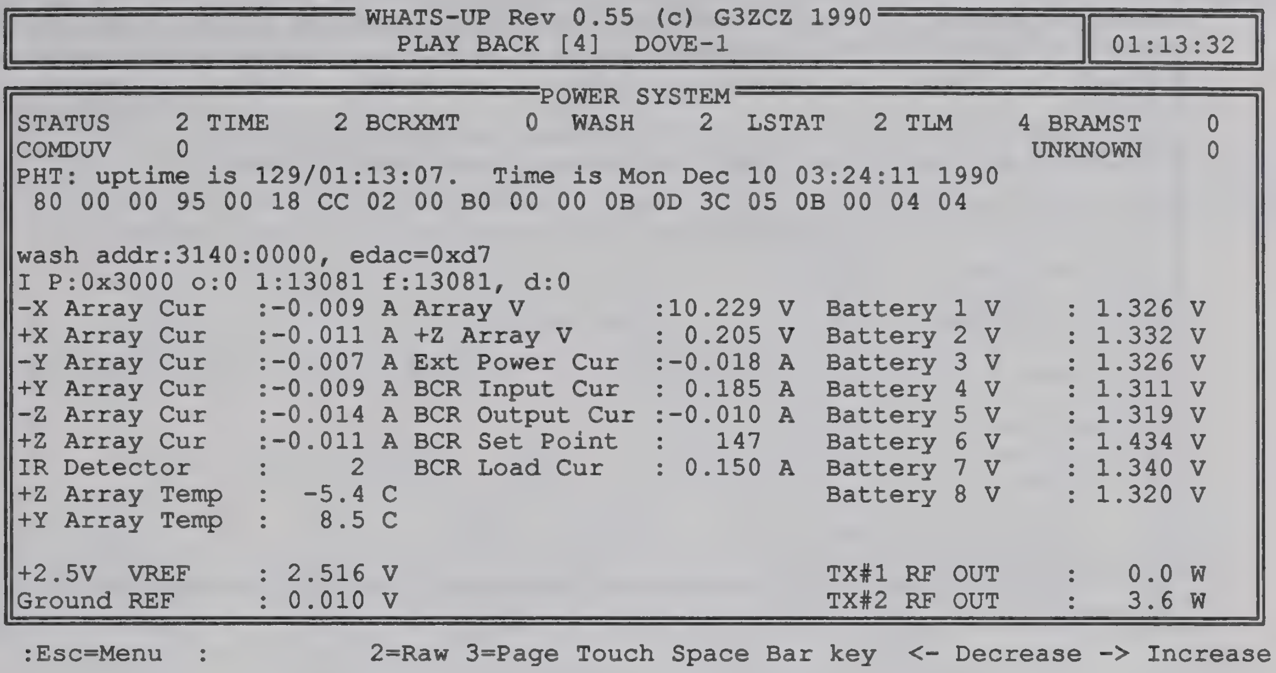
WHATS-UP version 0.55 by Joe Kasser, W3/G3ZCZ has a somewhat misleading title and a witty name for the accompanying document. Joe is working on incorporating the ability to decode many satellites using this one program. At the main menu simply select the satellite you wish to decode and provide the serial data. This is a well thought out, very configurable program. Once downloaded from CIS, use PKUNZIP to unzip(uncompress) it. The documentation is through, but direct. Just as with all versatile programs, there appears to be a great deal of complexity. The default values should provide everything you need to start, then you may re-configure the output as your needs change. Telemetry data is displayed in 5 screens. The default screen displays the POWER SYSTEM channels, the other screen channel groupings are: 2) the SPACECRAFT VOLTAGES; 3) the TEMPERATURES; 4) the PAYLOAD TRANSMITTER/RECEIVERS and 5) the RAW MESSAGES. Note that the 2 and 3 selections below the main box refer to function keys F2 and F3. The numbers selections displayed in the resultant boxes are the actual number keys. Figures 7.3 - 7.7 show examples of the 5 screens, all using the same data. Telemetry can be decoded both in realtime or in file playback mode. It is necessary to have a .D17 file extension for the program to recognize a data file. The extract function in the main menu is a great feature that gets selected channel data into spreadsheet format. With shareware you get to test drive the program, then register/pay for it if you find it useful. If you just want to decode DOVE telemetry this program accommodates. There is a TNC setting you may have to change, the header line must be on a separate line from the data. This can be accomplished in a text editor after the data has been stored or by changing the configuration of your TNC, (HEADERLINE ON). The STATUS and LSTAT line are displayed but not decoded. The display speed can be controlled by pressing the left cursor to slow down and right cursor to speed up. The channels whose values change are displayed in a different color, and those that exceed certain limits(that you may set) are flagged in red (or a color you may set). There are many more configurations possible. If you adopt the program, you may register it and get the most current version from Joe Kasser(of AMSAT Journal fame - editor/author). Joe is adding other satellites, so eventually you should be able to decode telemetry from all the satellites using just this one program.

Figure 7.3 sample screen display of G3ZCZ WHATS-UP DOVE decoding software.



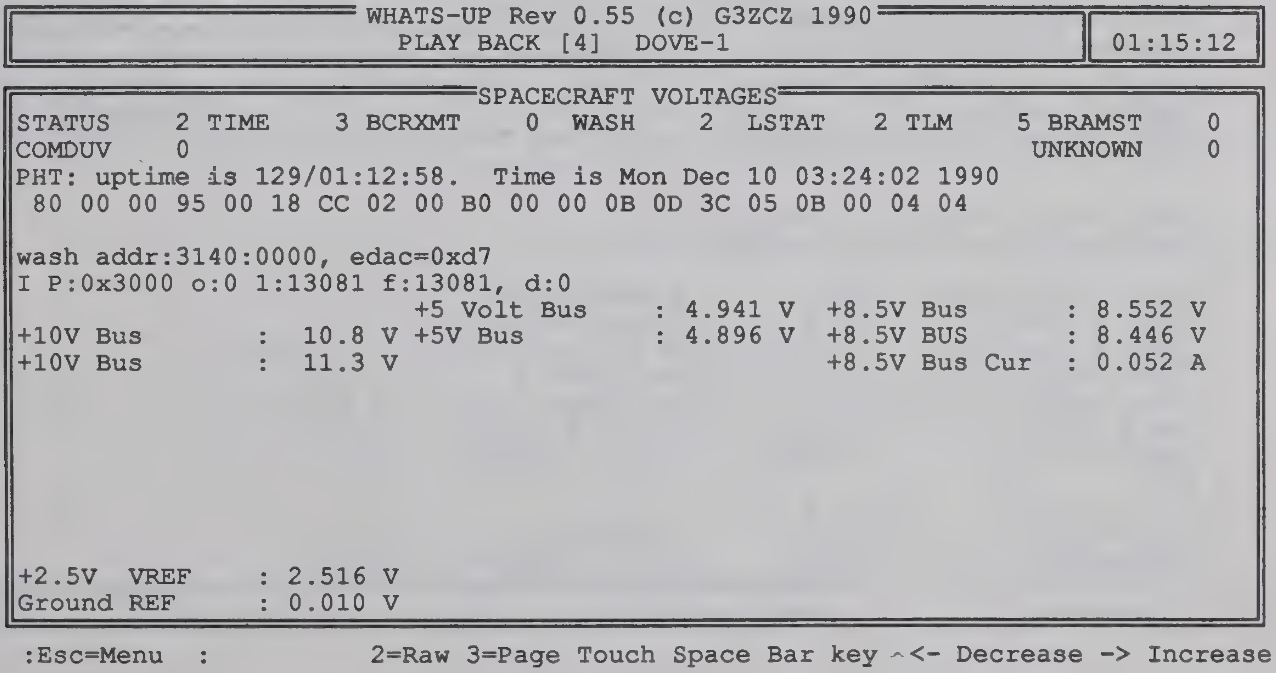
```
                    WHATS-UP Rev 0.55 (c) G3ZCZ 1990
                     PLAY BACK [4]  DOVE-1                      01:06:12

                                RAW MESSAGES
STATUS     2 TIME     2 BCRXMT     0  WASH     2  LSTAT    2 TLM     4 BRAMST     0
COMDUV     0                                                        UNKNOWN      0
PHT: uptime is 129/01:12:58.  Time is Mon Dec 10 03:24:02 1990
 80 00 00 95 00 18 CC 02 00 B0 00 00 0B 0D 3C 05 0B 00 04 04

wash addr:3140:0000, edac=0xd7
I P:0x3000 o:0 1:13081 f:13081, d:0
00:5A 01:5A 02:86 03:32 04:58 05:5A 06:6E 07:52 08:6B 09:73 0A:A2
0B:DC 0C:E9 0D:D8 0E:02 0F:25 10:D4 11:A8 12:01 13:02 14:A7 15:91
16:89 17:84 18:86 19:87 1A:88 1B:69 1C:89 1D:89 1E:2A 1F:5F 20:BE
21:AE 22:87 23:24 24:20 25:29 26:02 27:01 28:01 29:01 2A:01 2B:00
2C:01 2D:27 2E:02 2F:9E 30:CA 31:9E 32:14 33:D8 34:BF 35:97 36:A5
37:A5 38:AE




+2.5V  VREF     : 2.516 V
Ground REF      : 0.010 V
 :Esc=Menu  :           2=Raw 3=Page Touch Space Bar key  <- Decrease -> Increase
```

Figure 7.4 sample screen display of G3ZCZ WHATS-UP DOVE decoding software.



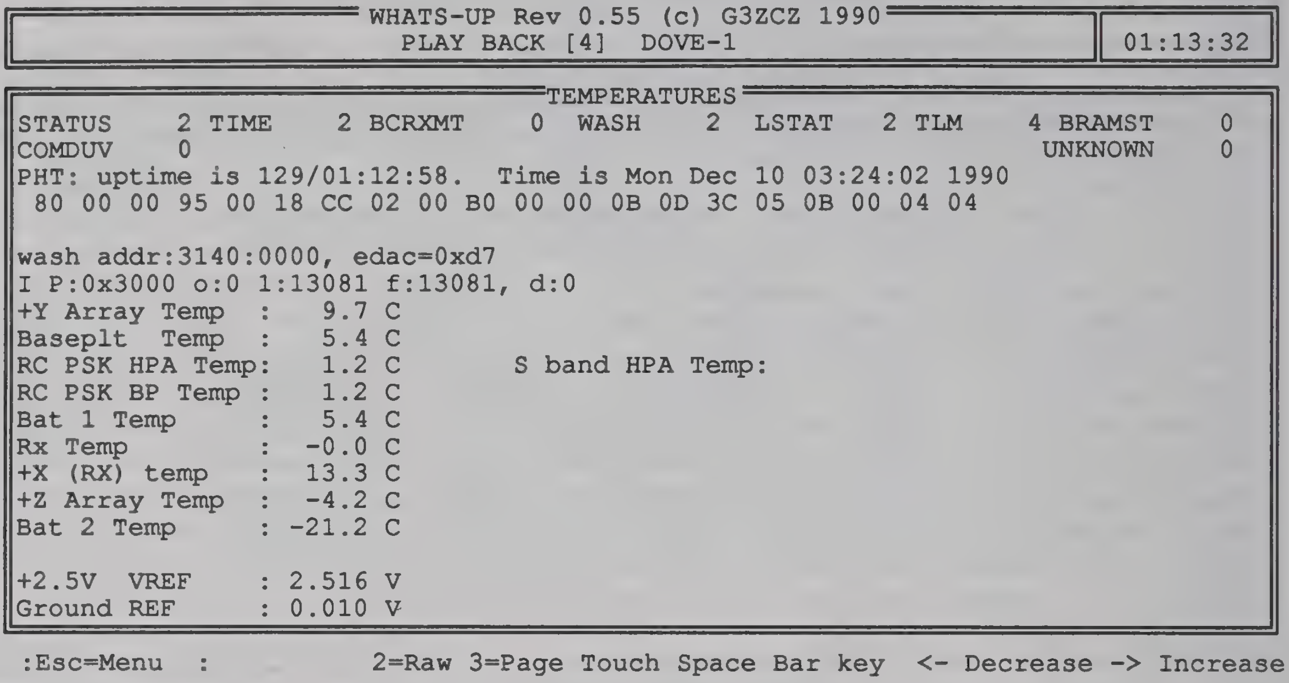
```
                WHATS-UP Rev 0.55 (c) G3ZCZ 1990
                  PLAY BACK [4]  DOVE-1                      01:13:32

                               POWER SYSTEM
STATUS     2 TIME     2 BCRXMT     0  WASH     2  LSTAT    2 TLM     4 BRAMST    0
COMDUV     0                                                       UNKNOWN     0
PHT: uptime is 129/01:13:07.  Time is Mon Dec 10 03:24:11 1990
 80 00 00 95 00 18 CC 02 00 B0 00 00 0B 0D 3C 05 0B 00 04 04

wash addr:3140:0000, edac=0xd7
I P:0x3000 o:0 1:13081 f:13081, d:0
-X Array Cur    :-0.009 A Array V          :10.229 V  Battery 1 V    : 1.326 V
+X Array Cur    :-0.011 A +Z Array V       : 0.205 V  Battery 2 V    : 1.332 V
-Y Array Cur    :-0.007 A Ext Power Cur    :-0.018 A  Battery 3 V    : 1.326 V
+Y Array Cur    :-0.009 A BCR Input Cur    : 0.185 A  Battery 4 V    : 1.311 V
-Z Array Cur    :-0.014 A BCR Output Cur   :-0.010 A  Battery 5 V    : 1.319 V
+Z Array Cur    :-0.011 A BCR Set Point    :    147   Battery 6 V    : 1.434 V
IR Detector     :       2   BCR Load Cur   : 0.150 A  Battery 7 V    : 1.340 V
+Z Array Temp   :   -5.4 C                            Battery 8 V    : 1.320 V
+Y Array Temp   :    8.5 C

+2.5V  VREF     : 2.516 V                             TX#1 RF OUT    :    0.0 W
Ground REF      : 0.010 V                             TX#2 RF OUT    :    3.6 W
 :Esc=Menu  :          2=Raw 3=Page Touch Space Bar key  <- Decrease -> Increase
```

Figure 7.5 sample screen display of G3ZCZ WHATS-UP DOVE decoding software.



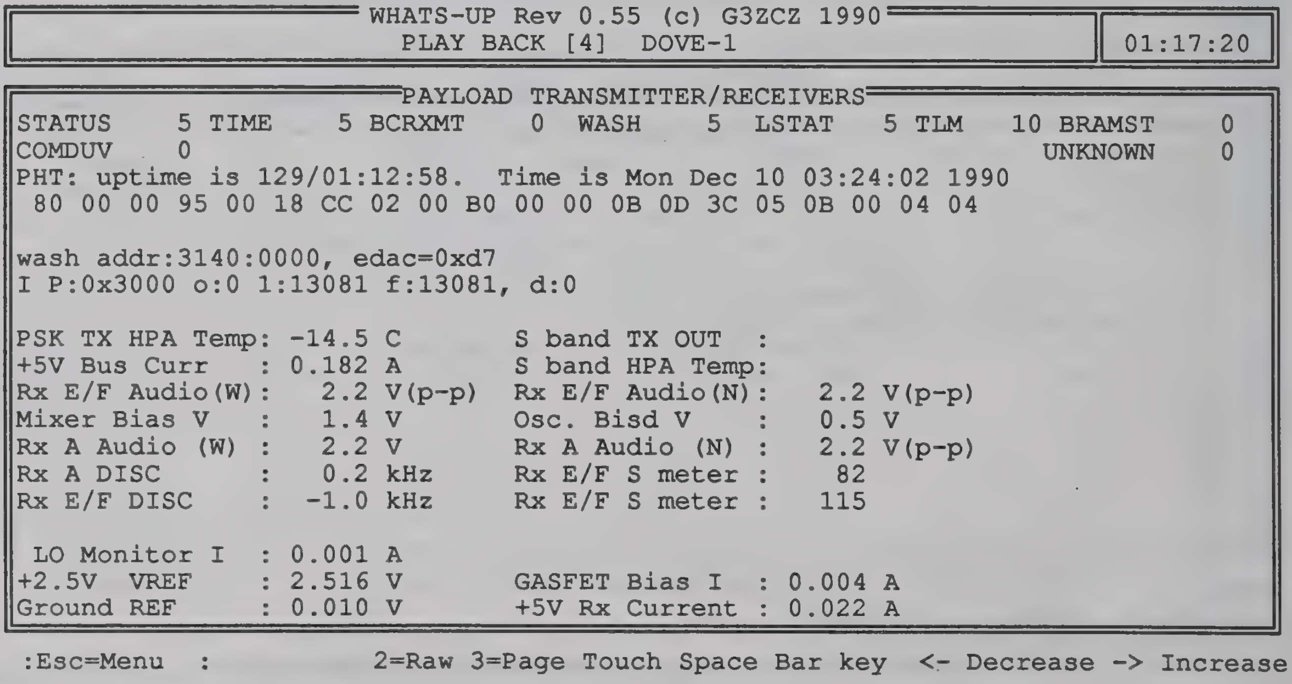
```
                WHATS-UP Rev 0.55 (c) G3ZCZ 1990
                  PLAY BACK [4]  DOVE-1                      01:15:12

                           SPACECRAFT VOLTAGES
STATUS     2 TIME     3 BCRXMT     0  WASH     2  LSTAT    2 TLM     5 BRAMST    0
COMDUV     0                                                       UNKNOWN     0
PHT: uptime is 129/01:12:58.  Time is Mon Dec 10 03:24:02 1990
 80 00 00 95 00 18 CC 02 00 B0 00 00 0B 0D 3C 05 0B 00 04 04

wash addr:3140:0000, edac=0xd7
I P:0x3000 o:0 1:13081 f:13081, d:0
                          +5 Volt Bus      : 4.941 V  +8.5V Bus      : 8.552 V
+10V Bus        :  10.8 V +5V Bus          : 4.896 V  +8.5V BUS      : 8.446 V
+10V Bus        :  11.3 V                             +8.5V Bus Cur  : 0.052 A







+2.5V  VREF     : 2.516 V
Ground REF      : 0.010 V
 :Esc=Menu  :          2=Raw 3=Page Touch Space Bar key  <- Decrease -> Increase
```

Figure 7.6 sample screen display of G3ZCZ WHATS-UP DOVE decoding software.



```
                    WHATS-UP Rev 0.55 (c) G3ZCZ 1990
                       PLAY BACK [4]  DOVE-1                   01:13:32

                                TEMPERATURES
STATUS     2 TIME     2 BCRXMT     0  WASH     2  LSTAT    2 TLM     4 BRAMST     0
COMDUV     0                                                         UNKNOWN      0
PHT: uptime is 129/01:12:58.  Time is Mon Dec 10 03:24:02 1990
 80 00 00 95 00 18 CC 02 00 B0 00 00 0B 0D 3C 05 0B 00 04 04

wash addr:3140:0000, edac=0xd7
I P:0x3000 o:0 1:13081 f:13081, d:0
+Y Array Temp  :   9.7 C
Baseplt  Temp  :   5.4 C
RC PSK HPA Temp:   1.2 C        S band HPA Temp:
RC PSK BP Temp :   1.2 C
Bat 1 Temp     :   5.4 C
Rx Temp        :  -0.0 C
+X (RX) temp   :  13.3 C
+Z Array Temp  :  -4.2 C
Bat 2 Temp     : -21.2 C

+2.5V  VREF    : 2.516 V
Ground REF     : 0.010 V

 :Esc=Menu  :           2=Raw 3=Page Touch Space Bar key  <- Decrease -> Increase
```

Figure 7.7 sample screen display of G3ZCZ WHATS-UP DOVE decoding software.



```
                    WHATS-UP Rev 0.55 (c) G3ZCZ 1990
                       PLAY BACK [4]  DOVE-1                   01:17:20

                       PAYLOAD TRANSMITTER/RECEIVERS
STATUS     5 TIME     5 BCRXMT     0  WASH     5  LSTAT    5 TLM    10 BRAMST     0
COMDUV     0                                                         UNKNOWN      0
PHT: uptime is 129/01:12:58.  Time is Mon Dec 10 03:24:02 1990
 80 00 00 95 00 18 CC 02 00 B0 00 00 0B 0D 3C 05 0B 00 04 04

wash addr:3140:0000, edac=0xd7
I P:0x3000 o:0 1:13081 f:13081, d:0

PSK TX HPA Temp: -14.5 C        S band TX OUT   :
+5V Bus Curr   : 0.182 A        S band HPA Temp:
Rx E/F Audio(W):   2.2 V(p-p)   Rx E/F Audio(N):   2.2 V(p-p)
Mixer Bias V   :   1.4 V        Osc. Bisd V     :   0.5 V
Rx A Audio (W) :   2.2 V        Rx A Audio (N)  :   2.2 V(p-p)
Rx A DISC      :   0.2 kHz      Rx E/F S meter  :   82
Rx E/F DISC    :  -1.0 kHz      Rx E/F S meter  :   115

 LO Monitor I  : 0.001 A
+2.5V  VREF    : 2.516 V        GASFET Bias I   : 0.004 A
Ground REF     : 0.010 V        +5V Rx Current  : 0.022 A

 :Esc=Menu  :           2=Raw 3=Page Touch Space Bar key  <- Decrease -> Increase
```

Harold Price, NK6K has a free, non-KISS mode decoding program available for download from CIS called NK6K-TLM. This program will display all the analog channels on one screen. Status points are not decoded. The headerline must be in the opposite sense from the G3ZCZ program. The headerline must be on the same line as the data, HEADERLINE OFF on your TNC. The program is invoked by redirecting (using as input) the filename containing the DOVE data to Harold's program.

C:>TLM1 <filename

All the frames received are displayed, but write over one another before they can be read. So you need to use CTRL/S to stop and any key to restart. Printer output is available for the last frame using the 'Shift/PrtSc' function. Figure 7.8 shows the screen display for this program.

Figure 7.8 sample screen output of NK6K's TLM1 DOVE decoding software

```
DOVE   uptime is 060/00:16:12.  Time is Tue Oct 02 02:25:29 199

Rx E/F Audio(W)     2.19 V Rx E/F Audio(N)     2.21 V Mixer Bias V:       1.41 V
Osc. Bisd V:        0.51 V Rx A Audio (W):     2.16 V Rx A Audio (N):     2.16 V
Rx A DISC:          0.23 k Rx A S meter:      75.00 C Rx E/F DISC:       -1.28 k
Rx E/F S meter:   108.00 C +5 Volt Bus:        4.94 V +5V Rx Current:     0.02 A
+2.5V  VREF:        2.51 V 8.5V BUS:           8.45 V IR Detector:        2.00 C
LO Monitor I:       0.00 A +10V Bus:          10.76 V GASFET Bias I:      0.00 A
Ground REF:         0.02 V +Z Array V:         0.41 V Rx Temp:           -8.47 D
+X (RX) temp:       3.02 D Bat 1 V:            1.33 V Bat 2 V:            1.32 V
Bat 3 V:            1.32 V Bat 4 V:            1.30 V Bat 5 V:            1.33 V
Bat 6 V:            1.44 V Bat 7 V:            1.33 V Bat 8 V:            1.31 V
Array V:           10.09 V +5V Bus:            4.93 V +8.5V Bus:          8.62 V
+10V Bus:          11.30 V BCR Set Point:    148.86 C BCR Load Cur:       0.14 A
+8.5V Bus Cur:      0.05 A +5V Bus Cur:        0.19 A -X Array Cur:      -0.01 A
+X Array Cur:      -0.01 A -Y Array Cur:      -0.01 A +Y Array Cur:      -0.01 A
-Z Array Cur:      -0.01 A +Z Array Cur:      -0.01 A Ext Power Cur:     -0.02 A
BCR Input Cur:      0.19 A BCR Output Cur:    -0.01 A Bat 1 Temp:         1.81 D
Bat 2 Temp:       -26.02 D Baseplt Temp:       1.81 D FM TX#1 RF OUT:     0.03 W
FM TX#2 RF OUT:     2.99 W PSK TX HPA Temp   -21.18 D +Y Array Temp:      3.02 D
RC PSK HPA Temp    -3.63 D RC PSK BP Temp:    -3.63 D +Z Array Temp:    -14.52 D


80  00  00  97  00  18  bb  02  00  b0  00  00  0a  0c  3c  05  0b  00  04  04
```

Decoding the TIME-1 telemetry line

```
DOVE-1>TIME-1:PHT: uptime is 180/00:40:16.  Time is Wed Jan 30 02:51:20 1991
```

The telemetry time line on the microsats identifies the satellite, gives the current UTC day and time. Uptime is the decimal number of days, hours, minutes and seconds that the current software has been running.

Decoding the LSTAT telemetry line

```
DOVE-1>LSTAT:I P:0x3000 o:0 l:13081 f:13081, d:0
```

LSTAT stands for Load Status. It describes the status of software uploading. This could be either a new operating system (the command and control software for the satellite operation) or task (specific function for the satellite). Following the LSTAT:

I/A	I for Inactive load status or A for Active upload in progress.
P:0x	4 digit hexadecimal address for the last program/task started
o:	overflow; decimal number of bytes in the AX.25 downlink buffer that were lost (thrown away) because the output buffer was full
l:	left, amount of contiguous edac memory remaining (decimal number)
f:	free, total amount of free memory; equal to or greater than the 'l' value previously defined (decimal number)
d:	digipeater status, 1 = active, 0 = OFF
st:	refers to the number of the last task started

Decoding the BCRXMT data line

```
DOVE-1>BCRXMT:vmax=752061 battop=740556 temp=-534412
```

The BCRXMT line provides information on the charging rate of the batteries relative to their temperature. Divide the values by 65536. Battop is a fixed setpoint, vmax is calculated depending upon the temperature of the batteries.

Decoding the WASH telemetry line

```
DOVE-1>WASH:wash addr:3640:0000, edac=0x3f
```

WASH means to clean out the SEUs (single event upset, memory error) from the edac (error detecting and correcting) memory. The address is the current location of the operating system while it is looping through memory correcting the errors. The number following edac is the total number of errors found.

STATUS line

The byte definitions for each byte and its position are not currently firm. These will be defined in the next edition.

```
DOVE-1>STATUS: 80 00 00 8F 00 18 CC 02 00 B0 00 00 0C 0E 3C 05 0B 00 04 04
```

Table 7.1 DOVE Telemetry Decoding Formulae

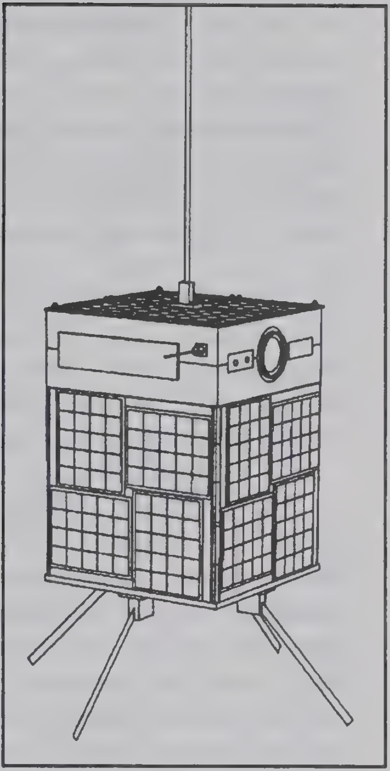
Channel	Label	A	B	C	units
0	Rx E/F Audio(W)	+0.000	+0.0246	0.000	V(p-p)
1	Rx E/F Audio(N)	+0.000	+0.0246	0.000	V(p-p)
2	Mixer Bias V:	+0.000	+0.0102	0.000	Volts
3	Osc. Bias V:	+0.000	+0.0102	0.000	Volts
4	Rx A Audio (W):	+0.000	+0.0246	0.000	V(p-p)
5	Rx A Audio (N):	+0.000	+0.0246	0.000	V(p-p)
6	Rx A DISC:	+10.427	-0.09274	0.000	kHz
7	Rx A S meter:	+0.000	+1.000	0.000	Counts
8	Rx E/F DISC:	+9.6234	-0.09911	0.000	kHz
9	Rx E/F S meter:	+0.000	+1.000	0.000	Counts
A	+5 Volt Bus:	+0.000	+0.0305	0.000	Volts
B	+5V Rx Current:	+0.000	+0.000100	0.000	Amps
C	+2.5V VREF:	+0.000	+0.0108	0.000	Volts
D	8.5V BUS:	+0.000	+0.0391	0.000	Volts
E	IR Detector:	+0.000	+1.000	0.000	Counts
F	LO Monitor I:	+0.000	+0.000037	0.000	Amps
10	+10V Bus:	+0.000	+0.05075	0.000	Volts
11	GASFET Bias I:	+0.000	+0.000026	0.000	Amps
12	Ground REF:	+0.000	+0.0100	0.000	Volts
13	+Z Array V:	+0.000	+0.1023	0.000	Volts
14	Rx Temp:	+101.05	-0.6051	0.000	Deg. C
15	+X (RX) temp:	+101.05	-0.6051	0.000	Deg. C
16	Bat 1 V:	+1.7932	-0.0034084	0.000	Volts
17	Bat 2 V:	+1.7978	-0.0035316	0.000	Volts
18	Bat 3 V:	+1.8046	-0.0035723	0.000	Volts
19	Bat 4 V:	+1.7782	-0.0034590	0.000	Volts
1A	Bat 5 V:	+1.8410	-0.0038355	0.000	Volts
1B	Bat 6 V:	+1.8381	-0.0038450	0.000	Volts
1C	Bat 7 V:	+1.8568	-0.0037757	0.000	Volts
1D	Bat 8 V:	+1.7868	-0.0034068	0.000	Volts
1E	Array V:	+7.205	+0.07200	0.000	Volts
1F	+5V Bus:	+1.932	+0.0312	0.000	Volts
20	+8.5V Bus:	+5.265	+0.0173	0.000	Volts
21	+10V Bus:	+7.469	+0.021765	0.000	Volts
22	BCR Set Point:	-8.762	+1.1590	0.000	Counts
23	BCR Load Cur:	-0.0871	+0.00698	0.000	Amps
24	+8.5V Bus Cur:	-0.00920	+0.001899	0.000	Amps
25	+5V Bus Cur:	+0.00502	+0.00431	0.000	Amps
26	-X Array Cur:	-0.01075	+0.00215	0.000	Amps
27	+X Array Cur:	-0.01349	+0.00270	0.000	Amps
28	-Y Array Cur:	-0.01196	+0.00239	0.000	Amps
29	+Y Array Cur:	-0.01141	+0.00228	0.000	Amps
2A	-Z Array Cur:	-0.01653	+0.00245	0.000	Amps
2B	+Z Array Cur:	-0.01137	+0.00228	0.000	Amps
2C	Ext Power Cur:	-0.02000	+0.00250	0.000	Amps
2D	BCR Input Cur:	+0.06122	+0.00317	0.000	Amps
2E	BCR Output Cur:	-0.01724	+0.00345	0.000	Amps
2F	Bat 1 Temp:	+101.05	-0.6051	0.000	Deg. C
30	Bat 2 Temp:	+101.05	-0.6051	0.000	Deg. C
31	Baseplt Temp:	+101.05	-0.6051	0.000	Deg. C
32	FM TX#1 RF OUT:	+0.0256	-0.000884	+0.0000836	Watts
33	FM TX#2 RF OUT:	-0.0027	+0.001257	+0.0000730	Watts
34	PSK TX HPA Temp	+101.05	-0.6051	0.000	Deg. C
35	+Y Array Temp:	+101.05	-0.6051	0.000	Deg. C
36	RC PSK HPA Temp	+101.05	-0.6051	0.000	Deg. C
37	RC PSK BP Temp:	+101.05	-0.6051	0.000	Deg. C
38	+Z Array Temp:	+101.05	-0.6051	0.000	Deg. C
39	S band HPA Temp	+101.05	-0.6051	0.000	Deg. C
3A	S band TX Out:	+0.0451	+0.00403	0.000	Watts

The general formula used to convert DOVE telemetry is : $Y = A + X(B + (X*C))$

March 5, 1991

WO-18

Name(s): WEBERSAT, Microsat
Object #: 20441
International ID: 1990-005F
Launch: 22 JAN 1990
Period: 100.8 minutes
Increment: 25.2° West
Orbit: LEO
Altitude: perigee 780 km
apogee 804 km



Modulation type(s): 1200 bps PSK AX.25

Sponsoring organization: CAST
(Center for Aerospace Studies)
at Weber State University

Downlink: 437.100 MHz(p) 437.075 MHz(s)

Telemetry equipment:
pointable 437 MHz antenna with preamp,
437 MHz SSB receiver, 1200 bps PSK modem,
TNC with KISS, computer

Software: TLMDCT from AMSAT-NA or CIS HAMNET,
WEBERWARE from AMSAT-NA

Webersat is an engineering project of CAST at Weber State University. As such their are a number of interesting experiments aboard that send the experimental data down on the telemetry beacon. WEBERSAT's mission is to provide an easily utilized, satellite based facility for video data acquisition and storage and transmission to Amateur Radio ground stations using Amateur packet radio techniques.

This microsat requires the same ground station equipment as FO-12, FO-20 and the other microsats (except DOVE). Figure 8.3 has a block diagram of the order in which to connect the telemetry receiving equipment. Since both the capturing and the decoding of the telemetry is done with Bob McGwier's TLMDC software, let's look at the telemetry format first.

WEBERSAT telemetry format

For the first few months after deployment all of the Microsats transmitted telemetry using a 7-bit ASCII AX.25 format. During the spring of 1990 the Microsat engineering team switched the telemetry on AO-16, WO-18 and LO-19 to an 8-bit hexadecimal format. Essentially this means that you can no longer directly read the data on your terminal screen or directly print the data. If you attempt to use a terminal/printer to display the raw telemetry, you will get font changes, bells, form feeds and assorted maladies. The changes have been implemented to effect a much faster transfer of data. Only a change in the software program used to capture and decode the data was necessary. Because telemetry shares the downlink frequency and transmitter with the main mission of the microsats, it is only sensible to make the telemetry transmission as efficient as possible. The telemetry complexity has increased as a result of making the telemetry more efficient. These changes have been done in an orderly fashion, testing the changes and correcting problems before the next major change. Executable files for the IBM class of computers are available for capturing and decoding the telemetry soon after changes are implemented. Examples of the evolution of the telemetry are found in Figures 8.1 - 8.2. More changes may follow, but the basic telemetry format should be discernable throughout the changes.

The original microsat telemetry format was essentially the same format that DOVE uses today except WO-18 telemetry uses PSK modulation on SSB and DOVE uses AFSK modulation on FM. The data from the TNC was in plain ASCII. The telemetry channel data was identified by the TLM packet address field and sent in AX.25 packets. This was quite easy to read with a standard terminal or terminal emulator program running on any computer.

The spring of 1990 saw the first change toward a more efficient telemetry format. This change was made to allow more time for the transmission of PHOTO data. Figure 8.1 has an example of this telemetry version. Whole Orbit Data(WOD) was also added to assist the command stations in monitoring the satellite. The most noticeable part of this change was that much of the data was sent as 8-bit hexadecimal values rather than 7-bit ASCII. This meant that it was also necessary to have your TNC in KISS mode, which essentially passes all of the data demodulated by the TNC directly to the computer. The software in the computer decides how to process the raw data it has received. The TLMDC software was updated to accommodate this change. Those ground stations attempting to capture the data using a standard terminal or emulator ran into quite a problem. Most terminal programs don't store all the control codes, so even if it appeared that the data was being logged correctly it wasn't. Occasionally some lines and messages would be in ASCII and display correctly, and a number of graphics characters appeared on the screen. The cause of these graphic characters is hexadecimal data that corresponds to ASCII control codes. The telemetry channel identification and channel data are now sent for all 42h (67) channels in one packet. The 8-bit hexadecimal characters for the channel ID and channel data are now sent as 1 byte each. The original mode required two ASCII bytes for the channel and two bytes for the data plus a colon separator. So the telemetry went from 5 bytes/channel to 2 bytes/channel. The STATUS, LSTAT, BCRXMT, and PHOTO data values were also sent as hexadecimal bytes. Since I cannot directly print hexadecimal characters on paper, each hexadecimal value sent is written on the page as two ASCII characters. This is called a hex dump. I have also added spaces and <CR><LF>s to make the data more readable. Remember that this data comes down as a hexadecimal data stream. Since ASCII is a subset of hexadecimal data, messages would display in a readable format, but the non-ASCII data and control characters would cause your monitor or printer to behave erratically. TIME, STATUS, LSTAT, PHOTO, TLM and message packets are included in Figure 8.1.

Figure 8.1 Sample WO-18 PSK telemetry after change to hexadecimal mode

```
WEBER-1>TIME-1:PHT: Uptime is 089/09:25:25.  Time is Sat Aug 18 04:40:36 1990

WEBER-1>STATUS:C5C6CC2600000085B01888010093E7F507093C058E000000

WEBER-1>LSTAT:I P:0x1A9C o:0 l:1934 f:1934

WEBER-0>PHOTO-3:019f260005e00004e10006e0e10005e0e1e0e1e0e0e10005e0e1e0e1e10005
          0003e0e10007e0dfe1e0e0e0e1e0e1dfe10003e0e1e0f4012823232600060124
          1007080508000306080503202526a11c91dde0e2000be1e0e1e1e00003e1e0e1
          e0e1e0e0e1e1e00005e1e0e1e0e0e1e10009e0e1e0e10003e0e1e0e0e1e1e0e1
          e0e0e1e0e0e1e1e0e1e1e0e0e1e1e0e0e1e0e0e1e1e0e10005e0e1e0e0e1000a
          e0e10007e0e100oee0e1e0e0e1e10003e0e1e10004e0e1e0e0e1e10003e0e100
          05e0e10010e0e1e0e1e1e0dfe10003e0e1e1f401282323250006012511080508
          07070003060702202526a21c92dde1e2e20012e1e0e1e0e1e0e1e1e0e1e1e0e1

...  numerous other photo frames sent here

WEBER-1>TLM:E3C6CC26
       007A01730271037E047C059006770786087B09370AA60BA70CD00DBE0E080F75
       10B411901206137014AD15A616891783188019851A7E1B891C801D8C1E271F60
       2094217A2278233F243B252C26002700280029002A002B002C002D302E002FA6
       30A631A73237336D34B035B036BA37AE38D539A63AA63BA13C9B3DFF3E493FD6
       40A641A542D6

WEBER-1>STATUS:E3C6CC2600000085B01888010093E7F507093C058E000000

WEBER-1>CAST:

Current pic 5 is directly into sun.
Quite spectacular.  Will xmit it often
during the next few days.  Enjoy

73's WA3PSD
```

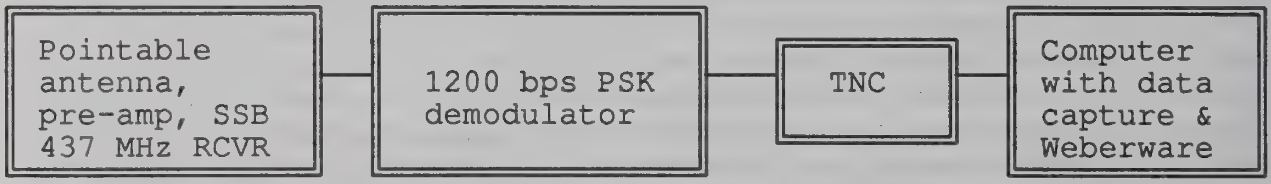
* *

In February 1991 WO-18 experienced a software crash, but was soon back on the air. The fact that the spin around the Z-axis of WO-18 slowed so much in late 1990 made it difficult to take pictures. After the new operating system was installed the camera software load was delayed. So no photos were being downlinked. The command station at Weber State used this to advantage to gather more WOD to better characterize the camera iris settings, spin and horizon sensors. Photo packets did resume the first week of March 1991. Figure 8.2 has some examples of the telemetry data from WO-18 February 28, 1991. There is an abundance of telemetry data to digest since the photo data is not interspersed. Appendix D contains a more complete picture of the downlinked hexadecimal data with the TNC in TRACE ON mode. Remember that the transmissions are downlinked in AX.25 protocol. A complete explanation of AX.25 protocol is available from the ARRL for those interested in understanding each of the hexadecimal values received. I have again taken some liberties in displaying the data in Figure 8.2, ASCII <CR>, <LF> and spaces have been inserted to make the data more readable. WEBERSAT will continue to send the WOD down as part of a regular sequence unlike PACSAT/LUSAT which sends the WOD down as files. The microsat software is still changing, so this format will probably change. If new software is necessary, it will be available from AMSAT-NA and probably on the CIS and DRIG.

Figure 8.2 sample WEBERSAT data after AO-16/LU-19 PBBS operational

```
WEBER-1>STATUS:0A78CC2700000084B018770100FBEFFF07093C058E000000

WEBER-1>LSTAT:I P:0x14C7 o:0 l:5897 f:6128, d:0 st:0

WEBER-1>TIME-1:PHT: uptime is 011/06:24:21.  Time is Thu Feb 28 03:26:58 1991

WEBER-1>STATUS:8278CC2700000084B018770100FBEFFF07093C058E000000

WEBER-1>WODCH:WOD:26 27 28 29 2A 2B

WEBER-1>LSTAT:I P:0x14C7 o:0 l:5897 f:6128, d:0 st:0

WEBER-1>TIME-1:PHT: uptime is 011/06:24:31.  Time is Thu Feb 28 03:27:08 1991

WEBER-1>STATUS:0A78CC2700000084B018770100FBEFFF07093C058E000000

WEBER-1>LSTAT:I P:0x14C7 o:0 l:5897 f:6128, d:0 st:0

WEBER-1>WOD:
4764C8270000000000005164C8270000000000005B64C827000000000000
6564C8270000000000006F64C8270000000000007964C827000000000000
8364C8270000000000008D64C8270000000000009764C827000000000000
A164C827000000000000AB64C827000000000000B564C827000000000000
BF64C827000000000000C964C827000000000000D364C827000000000000
DD64C827000000000000E764C827000000000000F164C827000001000000
FB64C8270000000000000565C8270000000000000F65C827000000000000
1965C8270000000000002365C8270000000000002D65C827000000000000
3765C827000000000000

WEBER-1>LSTAT:I P:0x14C7 o:0 l:5897 f:6128, d:0 st:0

WEBER-1>TLM:C878CC27
0070 017E 026C 038C 0475 059D 0672 0794 0878 0944 0AA5 0BA5 0CCE 0DBC
0E08 0F72 10B0 118E 1206 136B 14A9 15A2 1688 1780 187E 1984 1A7C 1B7F
1C7F 1D8A 1E28 1F60 2094 217C 2277 233E 2434 2546 2600 2700 2800 2901
2A00 2B00 2C00 2D34 2E00 2FA2 30A2 31A4 3236 3368 34A8 35AA 36B6 37AA
38D3 39A7 3AA3 3B48 3CBF 3DFF 3E48 3FD4 409E 419E 42D4
```

Figure 8.3 Diagram of WO-18 telemetry receiving station


Pointable antenna, pre-amp, SSB 437 MHz RCVR
1200 bps PSK demodulator
TNC
Computer with data capture & Weberware

Capturing the telemetry

Setup a receiving station using the example in Figure 8.3. As the Microsat comes above the horizon, tune to get the strongest beacon signal. Then watching the PSK unit re-tune to get both a TUNE and LOCK indication on the PSK demodulator. It is a full time job to manually keep the PSK unit tuned and locked with the satellite signal. It is almost mandatory to have the PSK unit control the receiver frequency. Receiving telemetry from horizon to horizon requires a pointable antenna. The signal may be strong enough above 10-15 degrees to receive it on stationary antenna, you decide how much of the telemetry you want to capture. The satellite moves rapidly, so it is necessary to track the satellite closely to maintain a good signal strength.

TAPR 1200 bps PSK modem switch settings:

MAN	means Manchester,not manual
USB/LSB	receiver sideband selected
PSK ON	
JOINT/SPLIT	this doesn't matter for telemetry reception

TNC-2 settings/commands:

```
PARITY 0
AWLEN 8
KISS ON
RESTART
```

N.B. Remember to command KISS OFF in the TNC before turning the power off.

Using the TLMDC software to capture telemetry and pictures

To capture the WO-18 telemetry and picture data, it is necessary to have both the computer and TNC configured with the same serial parameters. The default values for TLMDC are for COM1:9600,N,8,1 operation. To configure the TNC set the baud rate dip switches, and use the AWLEN and PARITY commands referenced above. The TLMDC software must have the 8 data bits and no parity configuration. The computer is configured using the mode command.

```
C:>mode COM1:9600,N,8,1 <CR or ENTER>
C:>TLMDC <CR or ENTER>
```

If you wish to run the TLMDC software at a different baud rate, this can be done by adding a serial configuration argument to the execution command. COM1 and N,8,1 must be used however. Limited success will occur if a baud rate below 2400 is selected.

```
C:>mode COM1:4800,N,8,1 <CR or ENTER>
C:>TLMDC COM1:4800,N,8,1 <CR or ENTER>
```

To decode the telemetry it is necessary to have the four files PACSAT, DOVE, WEBER, and LUSAT in the same directory as TLMDC. These files contain the calibration equations, no equations = no decoding. Currently DOVE is still in a straight ASCII format and cannot be decoded using TLMDC v4/10/90, only the microsats using the hexadecimal telemetry data. The telemetry data and any experimental data received all appear on the display screen when the TLMDC is run. Again since the TLM, PHOTO, STATUS, and LSTAT data are in hexadecimal you may get graphics characters in place of the actual data displayed on the screen.

switches, and use the AWLEN and PARITY commands referenced above. The TLMDC software must have the 8 data bits and no parity configuration. The computer is configured using the mode command.

```
C:>mode COM1:9600,N,8,1 <CR or ENTER>
C:>TLMDC <CR or ENTER>
```

If you wish to run the TLMDC software at a different baud rate, this can be done by adding a serial configuration argument to the execution command. COM1 and N,8,1 must be used however. Limited success will occur if a baud rate below 2400 is selected.

```
C:>mode COM1:4800,N,8,1 <CR or ENTER>
C:>TLMDC COM1:4800,N,8,1 <CR or ENTER>
```

To decode the telemetry it is necessary to have the four files PACSAT, DOVE, WEBER, and LUSAT in the same directory as TLMDC. These files contain the calibration equations, no equations = no decoding. Currently DOVE is still in a straight ASCII format and cannot be decoded using TLMDC v4/10/90, only the microsats using the hexadecimal telemetry data. The telemetry data and any experimental data received all appear on the display screen when the TLMDC is run. Again since the TLM, PHOTO, STATUS, and LSTAT data are in hexadecimal you may get graphics characters in place of the actual data displayed on the screen.

Select "D" to DUMP the data to a file as it is received or
"T" realtime decoding of the telemetry.

The "D" option will prompt for a "RAW" file and an "ASCII" file. Select descriptive filenames that describe the satellite, orbit number, date, or some combination of the three. "DUMP" will appear in the lower right hand corner, telling you the program is currently in DUMP mode and capable of logging data to a file as it comes in. All of the hexadecimal data is stored in the raw file and can be recalled for later decoding. Valid received data will print to the screen. Pressing the "D" key again will terminate the data storage function, but keep data printing to the screen. You may display or print the data stored in the ASC file.

Decoding telemetry on the microsats

The microsats are new and experimental spacecraft, so what is true today is not necessarily true tomorrow. Take note that the telemetry channels and format are all changeable. Since most of the data is in hexadecimal format it is almost mandatory to use a dedicated program to decode Microsat telemetry. If you must hand decode some channels, you need to look at the data using a program that will display the hexadecimal data. Get the data from the selected channel, convert it to decimal, and substitute it into the correct calibration equation. See the examples of hand decoding in the chapter on DO-17(DOVE). Survey data shows that approximately 50% of the people operating on the satellites use IBM based machines. So for now the software will be available first for these machines. Joe Kasser is working on an addition to his WHATS-UP program to include the binary data from the microsats. He has developed telemetry format conversion routines that allows decoding of most of the telemetry from most of the amateur satellites using one decoding program. When the microsat format stabilizes there will be a version of WHATS-UP that will decode DOVE, FO-20, UO-11, AO-13 and the microsats. Today we have software provided by Bob McGwier to capture and decode telemetry from the microsats. TLMDCT.ZIP is available from AMSAT-NA and CIS HAMNET. Make sure that you have the PKUNZIP.EXE file to 'unzip' Bob's program.

Decoding using the TLMDC software

Software decoding of the hexadecimal Microsat telemetry is most commonly done using the TLMDC.EXE program. Start the TLMDC program just as described in the section on capturing telemetry using TLMDC. To decode telemetry during reception, simply press the "T" key. This will initiate a screen display of the next received telemetry block. This screen is updated as each new TLM frame is received. Pressing the "T" key again will stop the realtime telemetry decoding and return you to the incoming data display screen. Figure 8.4 has a sample of the screen output after selecting the 'T' (telemetry) menu selection. If you wish to review some old telemetry data, you must have a file that stored the data while the TNC was in KISS mode. Both the TLMDC.EXE and the PB.EXE programs produce files of the correct type. With TLMDC running select the "F" option. This option prompts you to enter the filename which contains the data that you wish to decode. The first telemetry frame it finds in the selected file is then displayed on the screen. This display also resembles Figure 8.4. Pressing the <SPACE BAR> will display the next telemetry frame. When no more telemetry data is found, pressing the <SPACE BAR> again will return you to the main menu. You will need to know the exact filename when you enter the program, there is no provision to get a list of filenames in the current directory while the program is running.

N.B. WEBERSAT channel 38h, +Z Array temp is giving artificial data, its is believed that the wire to the thermistor is not connected.

Figure 8.4 sample TLMDC telemetry decoding screen using data from Figure 9.2

```
uptime is 205/08:17:19.  Time is Wed Dec 12 04:50:50 1990             WEBER
Rx D DISC        0.438 k  Rx D S meter   126.000 C  Rx C DISC        0.591 k
Rx C S meter   137.000 C  Rx B DISC        1.524 k  Rx B S meter   161.000 C
Rx A DISC        0.517 k  Rx A S meter   149.000 C  Rx E/F DISC     -1.032 k
Rx E/F S meter  69.000 C  +5 Volt Bus      5.778 V  +5V Rx Current   0.039 A
+2.5V  VREF      2.727 V  8.5V BUS         9.746 V  IR Detector      8.000 C
LO Monitor I     0.004 A  +10V Bus        13.499 V  GASFET Bias I    0.004 A
Ground REF       0.060 V  +Z Array V      10.639 V  Rx Temp          0.742 D
+X (RX) Temp     4.330 D  Bat 1 V          1.364 V  Bat 2 V          1.369 V
Bat 3 V          1.372 V  Bat 4 V          1.374 V  Bat 5 V          1.368 V
Bat 6 V          1.393 V  Bat 7 V          1.371 V  Bat 8 V          1.352 V
Array V         10.720 V  +5V Bus          4.771 V  +8.5V Bus        8.535 V
+10V Bus        10.975 V  BCR Set Point  129.128 C  BCR Load Cur     0.350 A
+8.5V Bus Cur    0.047 A  +5V Bus Cur      0.158 A  -X Array Cur    -0.001 A
+X Array Cur     0.009 A  -Y Array Cur    -0.010 A  +Y Array Cur    -0.012 A
-Z Array Cur    -0.015 A  +Z Array Cur    -0.021 A  Ext Power Cur   -0.020 A
BCR Input Cur    0.118 A  BCR Output Cur  -0.030 A  Bat 1 Temp       4.928 D
Bat 2 Temp       4.330 D  Baseplate Temp   4.928 D  PSK TX RF Out    0.074 W
RC PSK TX Out    1.297 W  PSK TX HPA Tem   1.340 D  +Y Array Temp    0.742 D
RC PSK HPA Tem  -5.238 D  RC PSK BP Temp   0.144 D  +Z Array Temp  209.000 C

         Total Array C= 0.009 Bat Ch Cur=-0.350 Ifb= 0.108 I+10V= 0.242
TXA:0 TXB:0 TX Pwr:0, BCR:3B3E                       Q=Quit,space to continue
```

Decoding the STATUS data line

```
WEBER-1>STATUS:0A78CC2700000084B018770100FBEFFF07093C058E000000
```

The meaning and order of each byte in the status line is still changing. So to avoid confusion it is not decoded here, but will be decoded in a later edition of this handbook.

Decoding the TIME-1 data line

```
WEBER-1>TIME-1:PHT: uptime is 011/06:24:21.  Time is Thu Feb 28 03:26:58 1991
```

The time line on the microsats identifies the satellite, gives the current UTC day and time. Uptime is the decimal number of days, hours, minutes and seconds that the current software has been running.

Decoding the LSTAT data line

```
WEBER-1>LSTAT:I P:0x14C7 o:0 l:5897 f:6128, d:0 st:0
```

LSTAT stands for Load Status. It describes the status of software uploading. This could be either a new operating system (the command and control software for the satellite operation) or task (specific function for the satellite). Following the LSTAT:

I/A	I for Inactive load status or A for Active upload in progress.
P:0x	4 digit hexadecimal address for the last program/task started
o:	overflow; decimal number of bytes in the AX.25 downlink buffer that were lost (thrown away) because the output buffer was full
l:	left, amount of contiguous edac memory remaining (decimal number)
f:	free, total amount of free memory; equal to or greater than the 'l' value previously defined (decimal number)
d:	digipeater status, 1 = active, 0 = OFF
st:	refers to the last task started

Decoding the BCRXMT data line

```
WEBER-1>BCRXMT:vmax=749416 battop=753664 temp=198465
```

The BCRXMT line provides information on the charging rate of the batteries relative to their temperature. Divide the values by 65536. Battop is a fixed setpoint, vmax is calculated depending upon the temperature of the batteries.

Decoding the WASH data line

```
WEBER-1>WASH:wash addr:2f80:0000, edac=0xab
```

WASH refers to cleaning out the SEUs (single event upset, memory error) from the edac (error detecting and correcting) memory. The address is the current location of the operating system while it is looping through memory correcting the errors. The number following edac is the total number of errors found. The WASH data has now been incorporated into the STATUS line.

Microsat WOD

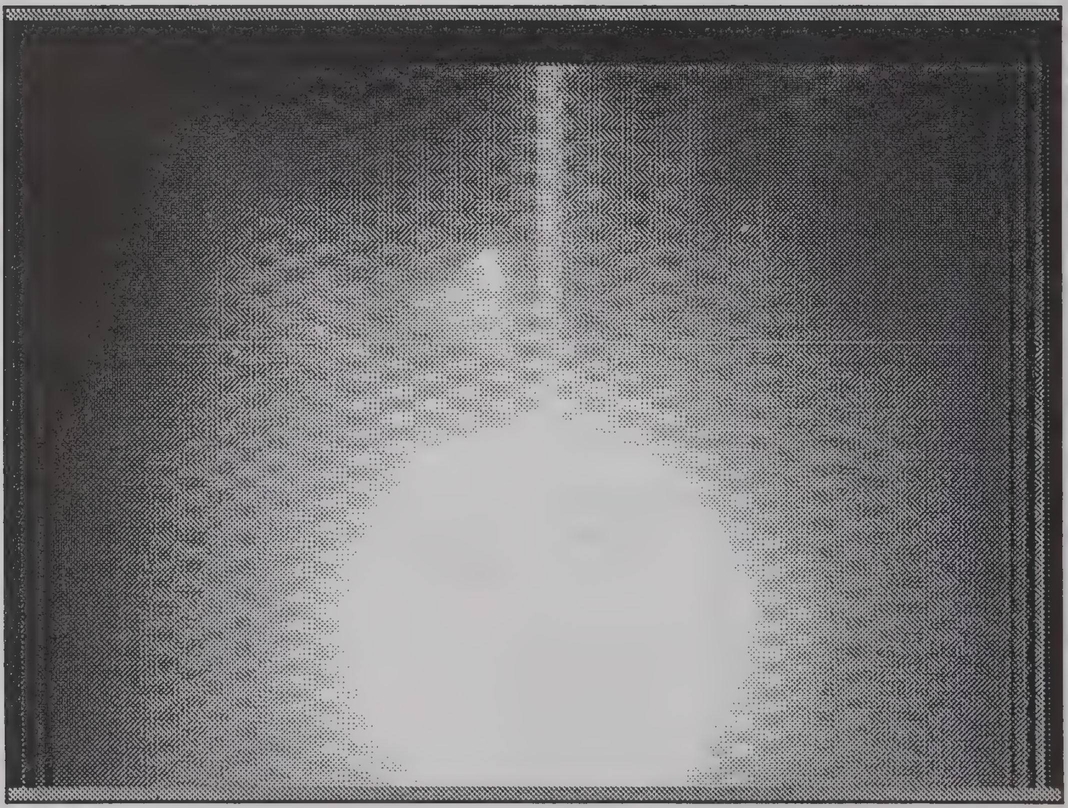
The microsats began sending WOD in the summer of 1990. The WOD is sent in 8-bit AX.25 packets with a packet address of WOD. Figure 8.2 contains a sample of WOD, Appendix D contains a longer listing. The first 4 bytes are the timestamp. The time format is the number of seconds elapsed since JAN 1, 1970. This is sometimes called UNIX time and familiar to IBM "C" programmers. The time is sent least significant byte first. The data follows the time, one byte per channel. Another packet frame is necessary to identify the channels sampled. Below is data from Figure 8.2 with <CR><LF> and spaces added for clarity. One special frame identifies the WOD channels, it uses packet address WODCH. A great deal of interesting information about what happens to the satellite as it circles the earth may be found by analyzing the WOD. Parse the WOD into a spreadsheet and see what you can find. The WOD channels sampled below and in Figure 8.2 are the array currents for all six sides of the spacecraft.

```
WEBER-1>WODCH:WOD:26 27 28 29 2A 2B

WEBER-1>WOD:
4764C827 00 00 00 00 00 00
5164C827 00 00 00 00 00 00
5B64C827 00 00 00 00 00 00
6564C827 00 00 00 00 00 00
6F64C827 00 00 00 00 00 00
7964C827 00 00 00 00 00 00
8364C827 00 00 00 00 00 00
8D64C827 00 00 00 00 00 00
9764C827 00 00 00 00 00 00
A164C827 00 00 00 00 00 00
AB64C827 00 00 00 00 00 00
B564C827 00 00 00 00 00 00
BF64C827 00 00 00 00 00 00
C964C827 00 00 00 00 00 00
D364C827 00 00 00 00 00 00
DD64C827 00 00 00 00 00 00
E764C827 00 00 00 00 00 00
F164C827 00 00 01 00 00 00
FB64C827 00 00 00 00 00 00
0565C827 00 00 00 00 00 00
0F65C827 00 00 00 00 00 00
1965C827 00 00 00 00 00 00
2365C827 00 00 00 00 00 00
2D65C827 00 00 00 00 00 00
3765C827 00 00 00 00 00 00
```

CCD experiment

This is the most publicized of the Webersat experiments. It takes pictures of the earth, digitizes them and sends them down to earth in binary packets. The color camera used in Webersat is a modified, commercial Canon 6I-10 CCD 35mm camera. The 700 x 400 pixel image is compressed and numbered line by line. The date/time the picture was taken is encoded in the packet header. It takes approximately 20 minutes to receive an entire picture, so more than 1 pass is required to receive a complete picture. The field of view of the camera has been found to be about 150 miles since WEBERSAT is only 800 km above the earth. Don't expect pictures that look like those taken from the weather satellites at 20,000 km. It is often difficult to pick out even well known landmarks over such a small area. Special software is also required to reassemble the multi-grey level picture. This software, known as Weberware v1.0, is available from AMSAT-NA. It will combine the individual frames, fill in missing frames, draw the image and even colorize it. There is a succinct documentation file included on the disk. There are multiple steps required to complete the conversion of captured CCD data to a presentation picture. As a point of reference, the camera lens points out of the +Y side of the spacecraft. The initial schedule calls for a switch of the image downloaded everyday at 5:45:26 UTC. There is enough ram aboard to hold 12 stored images. Figure 8.5 has sample WO-18 photo after it has been reassembled. This reproduction loses quite a bit of the resolution and you can notice the moiré patterns generated during the printing. The photo displayed on an EGA/VGA color monitor is quite striking. Figure 8.1 contains sample lines of PHOTO data.

Figure 8.5 sample WO-18 photo taken of the sun



Impact sensor

The impact sensor experiment was designed and built by students at Brighton High School, Sandy Utah. This experiment measures vibrations caused by small meteor impacts, as well as on board events such as closing the camera iris or thermal expansion/contraction. Scheduled about once a week, software will activate transmission of the impact sensor data at five second intervals. This will be in a 7 bit pure ASCII format. The piezo element is a strip (6" x 1.25") and located on a side of the spacecraft perpendicular to the camera lens. The value is interpreted as an 8 bit sum of voltages generated in response to microparticles striking the piezo element. Each impact increases the count by about 16. The count of 96 in Figure 8.6 says 6 impacts have occurred (6 x 16 = 96) since the last rollover. When the number of impacts exceeds 255 the values rollover through 0. The object is to count impacts per unit time.

Figure 8.6 sample WO-18 impact sensor data

```
WEBER-n>IMPACT-n>
Impact Counter Data:
01/05/90 01:15:20UTC  96
01/05/90 01:15:25UTC 112
01/05/90 01:15:30UTC 112
01/05/90 01:15:35UTC 128
01/05/90 01:15:40UTC 128
```

Horizon intercept sensor

This experiment is composed of 2 visible light photocells aimed through two holes adjacent to the camera lens. The photocell commands a 10 degrees conical field of view. The photocells are angled 11 degrees toward one another to form a 22 degree angle. These intersect about 1 foot in front of the spacecraft. Sensor 1 is closest to the outside of the craft. The theory of operation is that since the cone widens the farther the distance from the spacecraft. The earth is the only object able to illuminate both cells simultaneously. The sun cannot illuminate both. Illuminating a cell decreases the reading from that cell. The numbers are sent first for cell 1 then for cell 2. The timing of the data transmissions is controlled by the rate of change of the data. Samples are taken each second. If the cells are not illuminated, nothing is logged, except for a mandatory update each 5 minutes. When changes begin data is logged at a maximum one per second rate.

This information is also very useful in determining when to take a picture.

Figure 8.7 sample WO-18 horizon intercept sensor data

```
WEBER-n>HORIZON-n>
Horizon Intercept Data:
01/05/90 01:30:01UTC 255 255
01/05/90 01:35:01UTC 255 255
01/05/90 01:37:12UTC 255 254
01/05/90 01:37:13UTC 255 253
```

Magnetometer experiment

The are 2 magnetometers mounted orthogonal to one another inside Webersat. These will be used to measure fluctuations in the earth's magnetic field as the spacecraft rotates through it orbit. Magnetometer 1 is oriented to sense flux lines in the YZ plane, magnetometer 2 is oriented to measure in the XY plane. The numbers are not calibrated to any standard, they are to be referenced to previously collected magnetometer data. The format is basically the same as the other experiments. The samples are spaced at 5 second intervals.

Figure 8.8 sample WO-18 magnetometer data

```
WEBER-n>MAGNET-n>
Magnetometer Data:
01/15/90 01:30:15UTC 45 67
01/15/90 01:30:20UTC 47 82
01/15/90 01:30:25UTC 49 98
```

Spectrometer experiment

Webersat also contains a spectrometer experiment. This experiment is to provide data about the spectral content of light entering a slit in the -Y side of the spacecraft. The light is focused by a lens upon a diffraction grating then through another lens to a 2K x 1 byte CCD sensor. This result is converted by an ADC to the value stored in ram. The visible light spectra is the primary wavelength measured. A slightly different data format is used for this experiment. 8 data bits are used instead of 7. The transmissions will appear like the data in Figure 8.9. The data is divided into 'looks', these are snapshots that occupy 5k of memory each. This 'look' contains the illumination value of each cell of the CCD. The first character after the CR following the data text header is not actual data, but represents which of the 20 packets which are necessary to send the 5K of data. The data is sent as a stream of 8-bit ASCII characters. As of fall 1990 the software has not been uploaded for the spectrometer experiment.

Figure 8.9 sample WO-18 spectrometer data

```
WEBER-n>SPECT-n>
Spectrometer data follows. The data was taken starting on 01:30:90 at
01:15:35UTC with 5 seconds between looks and ending on 01:30:90 at
01:15:55UTC. Looks are separated by text saying "Look nn begins".
Look 01 begins
WEBER-n>SPECT-n>
&*ajajbkbkckclemememneofogpgpgogogoormcka ...
```

Other experiments

Also aboard is an L-band receiver for direct uplink of FSTV and digital voice data. These can use the DAC unit onboard to quickly convert memory values to analog values and then FM modulate a signal. This is a very rapid method of downloading a great deal of data quickly.

WEBERSAT calibration equation

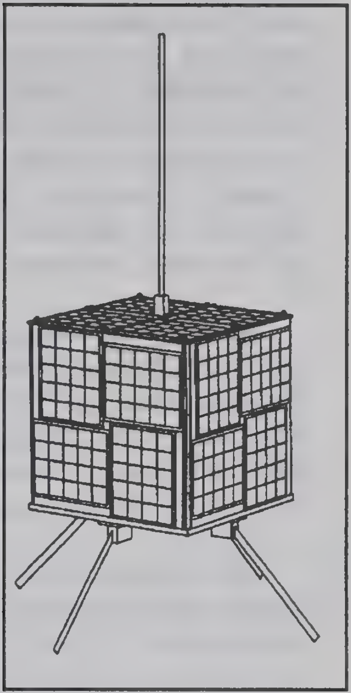
The constants to be use in the following formula are found in Table 8.1.
The general formula to use is: **$Y = A + X(B + (X*C))$, where X is the data received.**

Table 8.1 Webersat (WO-18) calibration definitions and constants

Channel	Description	A	B	C	
0	Rx D DISC:	+11.087	-0.08949	0.000	kHz
1	Rx D S meter:	+0.000	+1.000	0.000	Counts
2	Rx C DISC:	+10.322	-0.09448	0.000	kHz
3	Rx C S meter:	+0.000	+1.000	0.000	Counts
4	Rx B DISC:	+10.348	-0.09004	0.000	kHz
5	Rx B S meter:	+0.000	+1.000	0.000	Counts
6	Rx A DISC:	+11.387	-0.09535	0.000	kHz
7	Rx A S meter:	+0.000	+1.000	0.000	Counts
8	Rx E/F DISC:	+10.746	-0.09348	0.000	kHz
9	Rx E/F S meter:	+0.000	+1.000	0.000	Counts
A	+5 Volt Bus:	+0.000	+0.03523	0.000	Volts
B	+5V Rx Current:	+0.000	+0.000234	0.000	Amps
C	+2.5V VREF:	+0.000	+0.0133	0.000	Volts
D	RCVR 8.5V BUS:	+0.000	+0.0524	0.000	Volts
E	IR Detector:	+0.000	+1.000	0.000	Counts
F	LO Monitor I:	+0.000	+0.000033	0.000	Amps
10	RCVR +10V Bus:	+0.000	+0.0767	0.000	Volts
11	GASFET Bias I:	+0.000	+0.000026	0.000	Amps
12	Ground REF:	+0.000	+0.0100	0.000	Volts
13	+Z Array V:	+0.000	+0.1023	0.000	Volts
14	Rx Temp:	+100.01	-0.5980	0.000	Deg. C
15	+X (RX) Temp:	+100.01	-0.5980	0.000	Deg. C
16	Bat 1 V:	+1.8292	-0.0037196	0.000	Volts
17	Bat 2 V:	+1.8202	-0.0036943	0.000	Volts
18	Bat 3 V:	+1.8050	-0.0036721	0.000	Volts
19	Bat 4 V:	+1.8576	-0.0038979	0.000	Volts
1A	Bat 5 V:	+1.8095	-0.0037439	0.000	Volts
1B	Bat 6 V:	+1.8979	-0.0041754	0.000	Volts
1C	Bat 7 V:	+1.8246	-0.0038126	0.000	Volts
1D	Bat 8 V:	+1.7486	-0.0030475	0.000	Volts
1E	Array V:	+7.800	+0.06790	0.000	Volts
1F	+5V Bus:	+1.838	+0.0312	0.000	Volts
20	+8.5V Bus:	+5.793	+0.0184	0.000	Volts
21	+10V Bus:	+7.650	+0.0250	0.000	Volts
22	BCR Set Point:	-6.1963	+1.1277	0.000	Counts
23	BCR Load Cur:	-0.0405	+0.00620	0.000	Amps
24	+8.5V Bus Cur:	+0.00384	+0.000830	0.000	Amps
25	+5V Bus Cur:	-0.00763	+0.00394	0.000	Amps
26	-X Array Cur:	-0.00140	+0.00210	0.000	Amps
27	+X Array Cur:	+0.00946	+0.00226	0.000	Amps
28	-Y Array Cur:	-0.01018	+0.00224	0.000	Amps
29	+Y Array Cur:	-0.01168	+0.00239	0.000	Amps
2A	-Z Array Cur:	-0.01516	+0.00237	0.000	Amps
2B	+Z Array Cur:	-0.02111	+0.00239	0.000	Amps
2C	Ext Power Cur:	-0.02000	+0.00250	0.000	Amps
2D	BCR Input Cur:	-0.02189	+0.00332	0.000	Amps
2E	BCR Output Cur:	-0.03019	+0.00327	0.000	Amps
2F	Bat 1 Temp:	+100.01	-0.5980	0.000	Deg. C
30	Bat 2 Temp:	+100.01	-0.5980	0.000	Deg. C
31	Baseplate Temp:	+100.01	-0.5980	0.000	Deg. C
32	PSK TX RF Out:	+0.2104	-0.01203	+0.0001786	Watts
33	RC PSK TX Out:	+0.0340	-0.00969	+0.0002198	Watts
34	PSK TX HPA Temp	+100.01	-0.5980	0.000	Deg. C
35	+Y Array Temp:	+100.01	-0.5980	0.000	Deg. C
36	RC PSK HPA Temp	+100.01	-0.5980	0.000	Deg. C
37	RC PSK BP Temp:	+100.01	-0.5980	0.000	Deg. C
38	+Z Array Temp:	+0.0000	+1.0000	0.000	Counts
39	Horizon 1 (R):	+0.0000	+1.0000	0.000	units
3A	Spectrometer :	+0.0000	+1.0000	0.000	units
3B	Impact sensor:	+0.0000	+1.0000	0.000	units
3C	Horizon 2 (L):	+0.0000	+1.0000	0.000	units
3D	Magnet 1 (X) :	+0.0000	+1.0000	0.000	units
3E	Magnet 2 (Z) :	+0.0000	+1.0000	0.000	units
3F	unused temp :	+100.01	-0.59890	0.000	Deg. C
40	spectro temp :	+100.01	-0.59890	0.000	Deg. C
41	camera temp :	+100.01	-0.59890	0.000	Deg. C
42	unused temp :	+100.01	-0.59890	0.000	Deg. C

March 5, 1991

LO-19



Name(s): LUSAT, Microsat
Object #: 20442
International ID: 1990-005G
Launch: 22 JAN 1990
Period: 100.8 minutes
Increment: 25.2° West
Orbit: LEO
Altitude: perigee 780 km
apogee 804 km

Modulation type(s): 1200 bps PSK AX.25
12 WPM CW Telemetry
on 437.125 MHz

Sponsoring organization: AMSAT-LU (Argentina)

Downlink: 437.150 MHz(primary) SSB PSK
437.125 MHz(secondary) SSB PSK, CW

Telemetry equipment:
pointable 437 MHz antenna with preamp,
437 MHz SSB receiver/converter with external frequency up/down control,
1200 bps PSK modem, TNC, computer

Software: TLMDCT.ZIP from AMSAT-NA or CIS HAMNET
PBREL.ZIP from CIS HAMNET, CWTLM.BAS by WA4SXM

This AMSAT-LU satellite is the first satellite launched by or on behalf of Argentina. Its mission is to demonstrate Radio Amateur commitment to extending digital communications facilities; provide an easily utilized satellite based facility for data storage and forwarding using Amateur packet radio techniques. The microsats are in a sun synchronous orbit and appear over each location on earth 2-3 passes in the morning and 2-3 passes in the evening. In the southeastern United States this is usually between 9 am to 1 pm and 8 pm to midnight.

This microsat requires the same ground station equipment as FO-12 and FO-20, so new equipment isn't always necessary for each new satellite. Figure 9.3 has a block diagram of the order in which to connect the telemetry receiving equipment. Since both the capturing and the decoding of the telemetry is done with Bob McGwier's TLMDC software, let's look at the telemetry format first.

LUSAT telemetry format

For the first few months after deployment all of the Microsats transmitted telemetry using a 7-bit ASCII AX.25 format. During the spring of 1990 the Microsat engineering team switched the telemetry on AO-16, WO-18 and LO-19 to an 8-bit hexadecimal format. Essentially this means that you can no longer directly read the data on your terminal screen or directly print the data. If you attempt to use a terminal/printer to display the telemetry, you will get font changes, bells, form feeds and assorted maladies. The changes have been implemented to effect a much faster transfer of data. Only a change in the software program used to capture and decode the data was necessary. Because telemetry shares the downlink frequency and transmitter with the main mission of the microsats, it is only sensible to make the telemetry transmission as efficient as possible. The complexity of the telemetry has increased as a result of making the telemetrt more efficient. These changes have been done in an orderly fashion, testing the changes and correcting problems before the next major change. Executable files for the IBM class of computers are available for capturing and decoding the telemetry soon after the changes are implemented. More changes may follow, but the basic telemetry format should be discernable throughout the changes.

The original microsat telemetry format was essentially the same format that DOVE uses today except LO-19 telemetry uses PSK modulation on SSB where DOVE uses AFSK on FM. The data from the TNC was in plain ASCII. The telemetry channel data was identified by the TLM address field and sent in packets (see Figure 7.1). Each channel was identified and separated from its data by a colon. It was quite easy to read the telemetry with a standard terminal or terminal emulator program running on any computer.

The spring of 1990 saw the first change toward a more efficient telemetry format. This change was made to prepare for PBBS operation. Figure 9.1 has an example of this version of telemetry. Whole Orbit Data(WOD) was also added to assist the command stations in monitoring the satellite. The most noticeable part of this change was that much of the data was sent as 8-bit hexadecimal values rather than 7-bit ASCII. This meant that it was also necessary to put your TNC into KISS mode, which essentially passes all of the data demodulated by the TNC directly to the computer. The software in the computer decides how to process the raw data it has received. The TLMDC software was updated to accommodate this change. Those ground stations attempting to capture the data using a standard terminal or emulator run into quite a problem. Most terminal programs don't store all the control codes, so even if it appears that the data is being logged correctly it is't. Some lines and messages would be in ASCII and would display correctly, but a number of graphics characters appeared on the screen. These graphics characters are caused by hexadecimal data that corresponds to ASCII control codes. The telemetry channel identification and channel data were sent for all 3Ch (61) channels in one group. The 8-bit hexadecimal characters for the channel ID and channel data were now sent as 1 byte each. The original mode required two ASCII bytes for the channel and two for the data plus a colon separator. So the telemetry went from 5 bytes/channel to 2 bytes/channel. The STATUS, LSTAT and BCRXMT data values were also changed to hexadecimal bytes. Since ASCII is a subset of hexadecimal data, message and digi data would appear readable, but the non-ASCII and control characters cause unusual behavior by the screen/printer. I cannot directly print hexadecimal characters on paper, each hexadecimal value sent is written on the page as two ASCII characters. This is called a hex dump. I have also added spaces and <CR><LF>s to make the data more readable. Remember that this data comes down as a hexadecimal data stream. Examples of TIME, TLM, STATUS, LSTAT, message, BCRXMT, WASH and digipeated data are included in Figure 9.1.

Figure 9.1 Sample LUSAT telemetry before PBBS active

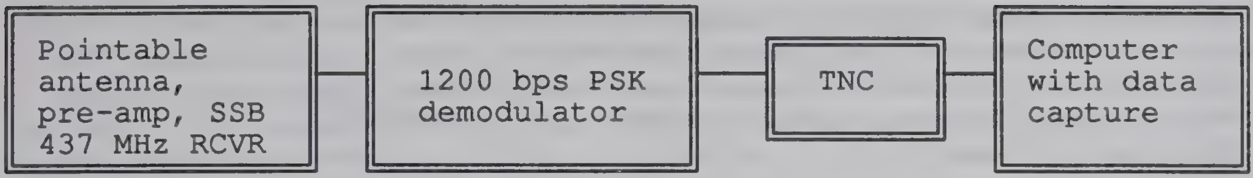
```
LUSAT-1>TIME-1:PHT: uptime is 028/11:26:00.  Time is Tue Oct 09 03:20:57 1990

LUSAT-1>TLM:89a41127
006c 0182 0276 0368 0471 0587 066c 0787 086c 097c 0aa4 0ba3 0ce8 0dda 0e00 0f3a
10d1 1184 1200 1302 14b4 15a4 1687 1785 1881 1986 1a80 1b77 1c7c 1d7e 1e26 1f5d
2081 217e 227c 2345 2432 2527 2601 2728 2800 2900 2a00 2b01 2c00 2d30 2e00 2f00
30a4 31a4 3200 3371 34a2 35a4 36c4 37a3 38bf 39a8 3aa8 3b02 3cff

LUSAT-1>STATUS:89a4112780000089b018aa01000900000b3c0504000000

LUSAT-1>LSTAT:I P:0x3000 o:15 l:10138 f:10138, d:1

HK3JHV-7>HK3HUC-10,LUSAT-1*:>

KJ1X>KJ1X,LUSAT-1*: hello-this is arnie in whitman, massachusetts

HK3JHV-7>HK3HUC-10,LUSAT-1*:>

LUSAT-1>TIME-1:PHT: uptime is 028/11:27:00.  Time is Tue Oct 09 03:21:57 1990

LUSAT-1>TLM:c5a41127
006d 0184 027a 036a 0475 0586 0618 0798 086c 097e 0aa4 0b9e 0ce8 0dd8 0e00 0f39
10d0 1184 1200 1302 14b5 15a4 168a 1785 1884 1986 1a84 1b7b 1c7c 1d84 1e26 1f5d
2081 217c 227b 2343 2432 252a 2600 2700 2801 2900 2a01 2b00 2c00 2d00 2e00 2fa4
30a3 31a4 3200 3372 34a3 35a6 36c4 37a6 38bf 39a9 3aa9 3b01 3cff

LUSAT-1>STATUS:c5a4112780000089b018aa01000900000b3c0505000000

LUSAT-1>LSTAT:I P:0x3000 o:15 l:10138 f:10138, d:1

LUSAT-1>WASH:wash addr:2f80:0000, edac=0xab

HK3JHV-7>HK3HUC-10,LUSAT-1*:>

KJ1X>HK3JHV-5,LUSAT-1*:3jhv-5 vusat-1

HK3JHV-5>KJ1X,LUSAT-1*:HELLO MY NAME JUAN EDUARDO IN BOGOTA COLOMBIA

      ...

LUSAT-1>AMARG:October 9, 0118Z.

WOD collection in progress.
We will analyze misc. TLM channels.

73 from Rio Gallegos
   (52 S, 69 W)
  Nestor,  LU7XAC
 LO-19 Control Team
  AMSAT ARGENTINA


LUSAT-1>BCRXMT:vmax=752071 battop=753664 temp=79503

LUSAT-1>LSTAT:I P:0x3000 o:15 l:10138 f:10138, d:1

LUSAT-1>WASH:wash addr:21c0:0000, edac=0xab
```

The store and forward BBS is now in place, so transmitter time is at a premium. All the data is a bit more cryptic than in the initial versions. The PBBS operation and file data contain hexadecimal data. The TLMDC program can still be used to capture and decode the telemetry. Figure 9.2 shows some example data after the PBBS became operational. Remember that these transmission use AX.25 protocol. This explains the extra hexadecimal characters associated with the packets. I am displaying this hex data stream with each non-ASCII byte represented as two ASCII numbers. The readable ASCII data is shown directly, and numerous space and <CR><LF> characters have been inserted for clarity. In the TLM data the channel identification is followed by the channel data for channels 00 - 3Ch. Hex file data, ASCII message, TIME, TLM, LSTAT, STAT, and BBSTAT are available in Figure 9.2. Appendix D contains a larger sample of data stored while the TNC had the TRACE ON. The microsat software is very versatile and can be changed to support systems under investigation. If new software is necessary, it will be available from AMSAT-NA and on the CIS and DRIG BBS.

Figure 9.2 Sample data from LUSAT after the PBBS operational

```
LUSAT-1>TIME-1:PHT: uptime is 017/00:18:59.  Time is Thu Feb 28 03:01:49 1991

LUSAT-1>TLM:9D72CC27
006E 0186 021C 037E 040C 0592 0624 0794 086A 0989 0AA3 0BA2 0CE8 0DD8 0E00 0F39
10D3 1183 1200 1302 14B1 15A2 1686 1782 1881 1982 1A7E 1B6E 1C7B 1D7B 1E28 1F5C
2081 2186 221A 2342 2436 2529 2600 2700 2800 2900 2A00 2B00 2C00 2D2B 2E00 2FA0
309E 31A1 3200 3373 34A0 35A2 36C2 37A1 38BB 39A6 3AA5 3B01 3CFF

LUSAT-12>WB9ANQ:
FD00AA55010004F7010000020008414C393130323238030003202020040004170A000005
00044E48CC270600044D72CC271200044C72CC27070001000800010C0900024C2F0A0002
790A0B00025000000000AA55010004F80100000200083237434336443346030003202020
04000486010000050004C7B9CC270600047C6FCC2707000100080001000900026D420A00
024A220B0002BF001000064C5534454E511100064C5534454E51120004C46DCC27130001
01140006564533424E4F1500062020202020201600040000000000170004C4B3D127180001
001900010026000A564533424E4F2E545854220014546B7320544C4D2F4469736B2E204C
553141

LUSAT-12>BBSTAT:Open AB D: WB9ANQ

LUSAT-1>TIME-1:PHT: uptime is 017/00:20:00.  Time is Thu Feb 28 03:02:50 1991

LUSAT-1>STATUS:DA72CC278000001EB018AA0102000000090B3C0500B40000

LUSAT-1>AMARG:
Feb 24.

We experiment NO BROADCAST on Wednesday.
All BBS performance reports will be apreciated.

73 de np LU7XAC
AMSAT ARGENTINA

LUSAT-1>LSTAT:I P:0x14C7 o:0 l:1645 f:1761, d:1 st:5

LUSAT-12>WB9ANQ:
dule the CW Beacon in the near future.  Is is no so easy as change  to TX-B  to TX-A.
The CW Beacon include mechanical movement (a RELAY with latch).  It disconnect the
Raised Cosine from the antena and connect the CW TX. That means that the
```

Figure 9.3 Diagram of LO-19 telemetry receiving station


Pointable antenna, pre-amp, SSB 437 MHz RCVR
1200 bps PSK demodulator
TNC
Computer with data capture

Capturing the telemetry

Setup a receiving station using the example in Figure 9.3. As the Microsat comes above the horizon, tune to get the strongest beacon signal. Then watching the PSK unit re-tune to get both a TUNE and LOCK indication on the PSK demodulator. It is a full time job to manually keep the PSK unit tuned and locked with the satellite signal. It is almost mandatory to have the PSK unit control the receiver frequency. Receiving telemetry from horizon to horizon requires a pointable antenna. The signal may be strong enough above 10-15 degrees elevation to receive it on a stationary antenna, you decide how much of the telemetry you want to capture. The satellite moves rapidly, so it is necessary to track the satellite closely to maintain a good signal strength.

TAPR 1200 bps PSK modem switch settings:

MAN	means Manchester, not manual
USB/LSB	receiver sideband selected
PSK ON	
JOINT/SPLIT	this doesn't matter for telemetry reception

TNC settings/commands:

PARITY 0
AWLEN 8
KISS ON
RESTART

N.B. Remember to command KISS OFF before turning the TNC power off.

Software to capture LUSAT Telemetry

Two programs are currently available for the IBM computers to capture the hexadecimal telemetry from LUSAT. TLMDC by Bob McGwier has been around and still works well, even though the downlink data has changed. The PB.EXE program by Jeff Ward can also be used to capture files transmitted in the PACSAT/LUSAT BROADCAST PROTOCOL FORMAT. Simply run the PB program and activate the KISS LOG ON item. The filename for the received data is automatically generated from the date the data is received and have a .KSS extension.

An alternate method of data capture is to use a terminal program that will store binary data. Few terminal programs will do this and it requires quite a robust test to determine whether your terminal program will work correctly. I have found 2 versions of PC-TALK to capture binary data correctly. Make sure that <CR>s are not changed to <CR><LF>, or any other control characters filtered or changed. ProComm will store everything except the 00 <NULL> character in the DOWNLOAD mode, but even fewer control characters in the LOG TO FILE mode. The fact that ProComm won't store all the characters makes it unusable for data capture. Attempts to print or display hex data will result in erratic behavior of your printer or nonsense screens. A utility program what can display stored hexadecimal data as ASCII characters is necessary if you wish to look at the data. Debug, Norton Utilities or (under Windows 3.0) IL or BROWSER (available on most BBS) will display both the hex and ASCII data to the screen.

Using the TLMDC software to capture telemetry

To capture the telemetry using the TLMDC software, it is necessary to have the computer, the TNC and the TLMDC program configured with the same serial parameters. The default values for TLMDC are COM1:9600,N,8,1 operation. To configure the TNC set the baud rate dip switches, and use the AWLEN and PARITY commands referenced above. TLMDC software must have the 8 data bits and no parity configuration. The IBM configuration is:

```
C:>mode COM1:9600,N,8,1 <CR or ENTER>
```

If you wish to run the TLMDC software at a different baud rate, this can be done by adding a serial configuration argument to the execution command. COM1 and N,8,1 must be used however. Make sure that the TNC, the computer and the program are using the same serial parameters! Limited success will occur if a baud rate below 2400 is selected.

```
C:>mode COM1:4800,N,8,1 <CR or ENTER>
C:>TLMDC COM1:4800,N,8,1 <CR or ENTER>
```

To decode the telemetry it is necessary to have the four files PACSAT, DOVE, WEBER, and LUSAT are in the same directory as TLMDC. These files contain the calibration equations, no equations = no decoding. Currently DOVE is still in a straight ASCII format and cannot be decoded using TLMDC v4/10/90, only the microsats using the hexadecimal telemetry data. Figure 9.1 & 9.2 are examples of LUSAT transmissions. The telemetry data and the conversation data digipeated both appear on the screen when the TLMDC is run. Again since the TLM, STATUS, and LSTAT data are in hexadecimal you may get graphics characters in place of actual data displayed on the screen.

Select "D" to DUMP the data to a file as it is received or
"T" realtime decoding of the telemetry.

The "D" option will prompt for a "RAW" file and an "ASCII" file. Select descriptive filenames that describe the satellite, orbit number, date, or some combination of the three. "DUMP" will appear in the lower right hand corner, telling you the program is currently in DUMP mode and capable of logging data to a file as it comes in. All of the hexadecimal data is stored in the raw file and can be recalled for later decoding. Valid ASCII data will print to the screen. Pressing the "D" key again will terminate the data storage function, but keep data printing to the screen. You may display or print the data stored in the ASC file.

Decoding telemetry on the microsats

The microsats are new and experimental spacecraft, so what is true today is not necessarily true tomorrow. Take note that the telemetry channels and format are all changeable. Since to decode microsat telemetry. If you must hand decode some channels, you need to look at the data using a program that will display the hexadecimal data. Get the data from the selected channel, convert it to decimal, and substitute it into the correct calibration equation. See the examples of hand decoding in the chapter on DO-17 (DOVE). Survey data shows that approximately 50% of the people operating on the satellites use IBM based machines. So for now the software will be available first for these machines. Joe Kasser is working on an addition to his WHATS-UP program to decode the binary data from the microsats. He has developed telemetry format conversion routines that allows decoding of most of the telemetry from most of the amateur satellites using one decoding program. When the microsat format stabilizes there will be a version of WHATS-UP that will decode DOVE, FO-20, UO-11, AO-13 and the microsats. Today we have software provided by Bob McGwier to decode telemetry from the microsats. TLMDCT.ZIP is available from AMSAT-NA and CIS HAMNET. Make sure that you have the PKUNZIP.EXE file to 'unzip' Bob's program.

Decoding using the TLMDC software

Software decoding of the hexadecimal microsat telemetry is most commonly done using the TLMDC.EXE program. Start the TLMDC program just as described in the section on capturing telemetry using TLMDC. To decode telemetry during reception, simply press the "T" key. This will initiate a screen display of the next received telemetry block. This screen is updated as each new TLM frame is received. Pressing any key will stop the realtime telemetry decoding and return you to the incoming data display screen. Figure 9.4 has a sample of the screen output after selecting the 'T' (telemetry) menu selection. If you wish to review some old telemetry data, you must have a file that stored the data while the TNC was in KISS mode. Both the TLMDC.EXE and the PB.EXE programs produce files of the correct type. With TLMDC running select the "F" option. This option prompts you to enter the filename which contains the data that you wish to decode. The first telemetry frame it finds in the selected file is then displayed on the screen. Pressing the <SPACE BAR> will display the next telemetry frame. When no more telemetry data is found, pressing the <SPACE BAR> again will return you to the main menu. You will need to know the exact filename when you enter the program, there is no provision to get a list of filenames in the current directory while the program is running.

Figure 9.4 sample TLMDC telemetry screen output using data from Figure 9.1

```
uptime is 011/12:42:08.  Time is Wed Dec 12 03:32:30 1990             LUSAT
Rx D DISC        0.321 k  Rx D S meter   132.000 C  Rx C DISC       -2.493 k
Rx C S meter   104.000 C  Rx B DISC       -0.190 k  Rx B S meter   136.000 C
Rx A DISC        0.029 k  Rx A S meter   137.000 C  Rx E/F DISC      0.983 k
Rx E/F S meter 124.000 C  +5 Volt Bus      4.941 V  +5V Rx Current   0.040 A
+2.5V  VREF      2.527 V  8.5V BUS         8.524 V  IR Detector      0.000 C
LO Monitor I     0.002 A  +10V Bus        10.922 V  GASFET Bias I    0.003 A
Ground REF       0.000 V  +Z Array V       0.102 V  Rx Temp         -2.674 D
+X (RX) Temp     5.740 D  Bat 1 V          1.368 V  Bat 2 V          1.372 V
Bat 3 V          1.377 V  Bat 4 V          1.368 V  Bat 5 V          1.375 V
Bat 6 V          1.549 V  Bat 7 V          1.371 V  Bat 8 V          1.365 V
Array V         11.088 V  +5V Bus          4.968 V  +8.5V Bus        7.988 V
+10V Bus        11.400 V  BCR Set Point  140.739 C  BCR Load Cur     0.396 A
+8.5V Bus Cur    0.043 A  +5V Bus Cur      0.191 A  +X Array Cur    -0.016 A
-X Array Cur    -0.012 A  -Y Array Cur     0.003 A  +Y Array Cur     0.001 A
-Z Array Cur     0.004 A  +Z Array Cur    -0.008 A  Ext Power Cur   -0.020 A
BCR Input Cur    0.127 A  BCR Output Cur   0.007 A  Bat 1 Temp       5.740 D
Bat 2 Temp       5.740 D  Baseplt Temp     3.496 D  PSK TX RF Out    0.107 W
RC PSK TX Out    1.275 W  PSK TX HPA Tem   9.666 D  +Y Array Temp    7.983 D
RC PSK HPA Tem -10.526 D  RC PSK BP Temp   7.983 D  +Z Array Temp   -8.283 D
LU Bcn Temp A    2.374 D  LU Bcn Temp D    3.496 D  Coax Rly Stat    1.000 C
Coax Rly Stat  255.000 C

         Total Array C= 0.008 Bat Ch Cur=-0.390 Ifb= 0.119 I+10V= 0.277
TXA:0 TXB:0 TX Pwr:0, BCR:3B3E                        Q=Quit,space to continue
```

* *

Decoding the STATUS line

```
LUSAT-1>STATUS:DA72CC278000001EB018AA0102000000090B3C0500B40000
```

The meaning and order of the status bytes is still changing. So to avoid confusion they are not defined here, but will be defined in a later edition of the handbook.

Decoding the TIME-1 telemetry line

```
LUSAT-1>TIME-1:PHT: uptime is 028/11:27:00.  Time is Tue Oct 09 03:21:57 1990
```

The telemetry time line on the microsats identifies the satellite, gives the current UTC day and time. Uptime is the decimal number of days, hours, minutes and seconds that the current software has been running.

Decoding the BBSTAT data line

This line is part of the PBBS system and tells which of the uplink channels are active and the stations that are connected.

```
LUSAT-12>BBSTAT:Open AB D: WB9ANQ
```

Decoding the LSTAT telemetry line

```
LUSAT-1>LSTAT:I P:0x14C7 o:0 l:1645 f:1761, d:1 st:5
```

LSTAT stands for Load Status. It describes the status of software uploading. This could be either a new operating system (the command and control software for the satellite operation) or task (specific function for the satellite). Following the LSTAT:

I/A	I for Inactive load status or A for Active upload in progress.
P:0x	4 digit hexadecimal address for the last program/task started
o:	overflow; decimal number of bytes in the AX.25 downlink buffer that were lost (thrown away) because the output buffer was full
l:	left, amount of contiguous edac memory remaining (decimal number)
f:	free, total amount of free memory; equal to or greater than the 'l' value previously defined (decimal number)
d:	digipeater status, 1 = active, 0 = OFF
st:	refers to the number of the last task started

Decoding the BCRXMT data line

```
LUSAT-1>BCRXMT:vmax=752071 battop=753664 temp=79503
```

The BCRXMT line provides information on the charging rate of the batteries relative to their temperature. Divide the values by 65536. Battop is a fixed setpoint, vmax is calculated depending upon the temperature of the batteries.

Decoding the WASH telemetry line

```
LUSAT-1>WASH:wash addr:2f80:0000, edac=0xab
```

WASH means to clean out the SEUs (single event upset, memory error) from the edac (error detecting and correcting) memory. The address is the current location of the operating system while it is looping through memory correcting the errors. The number following edac is the total number of errors found. The WASH data has now been incorportated into the STATUS line on LUSAT.

WOD frame

During 1990 WOD was sent down as hexadecimal AX.25 packet data with an address field of WOD. Since the PBBS system is now functional the WOD is available as a file that can be downloaded.

Table 9.1 LUSAT (LO-19) PSK telemetry calibration equations

Channel	Label	A	B	C	units
0	Rx D DISC:	+9.802	-0.08779	0.000	kHz
1	Rx D S meter:	+0.000	+1.000	0.000	Counts
2	Rx C DISC:	+8.429	-0.09102	0.000	kHz
3	Rx C S meter:	+0.000	+1.000	0.000	Counts
4	Rx B DISC:	+9.291	-0.08317	0.000	kHz
5	Rx B S meter:	+0.000	+1.000	0.000	Counts
6	Rx A DISC:	+9.752	-0.08310	0.000	kHz
7	Rx A S meter:	+0.000	+1.000	0.000	Counts
8	Rx E/F DISC:	+10.110	-0.08610	0.000	kHz
9	Rx E/F S meter:	+0.000	+1.000	0.000	Counts
A	+5 Volt Bus:	+0.000	+0.0305	0.000	Volts
B	+5V Rx Current:	+0.000	+0.000250	0.000	Amps
C	+2.5V VREF:	+0.000	+0.0108	0.000	Volts
D	8.5V BUS:	+0.000	+0.0391	0.000	Volts
E	IR Detector:	+0.000	+1.000	0.000	Counts
F	LO Monitor I:	+0.000	+0.000037	0.000	Amps
10	+10V Bus:	+0.000	+0.0508	0.000	Volts
11	GASFET Bias I:	+0.000	+0.000026	0.000	Amps
12	Ground REF:	+0.000	+0.0100	0.000	Volts
13	+Z Array V:	+0.000	+0.1023	0.000	Volts
14	Rx Temp:	+93.24	-0.5609	0.000	Deg. C
15	+X (RX) Temp:	+93.24	-0.5609	0.000	Deg. C
16	Bat 1 V:	+1.7343	-0.0029740	0.000	Volts
17	Bat 2 V:	+1.7512	-0.0032113	0.000	Volts
18	Bat 3 V:	+1.7790	-0.0034038	0.000	Volts
19	Bat 4 V:	+1.7286	-0.0030036	0.000	Volts
1A	Bat 5 V:	+1.8114	-0.0036960	0.000	Volts
1B	Bat 6 V:	+1.7547	-0.0032712	0.000	Volts
1C	Bat 7 V:	+1.7151	-0.0030739	0.000	Volts
1D	Bat 8 V:	+1.6846	-0.0028534	0.000	Volts
1E	Array V:	+8.100	+0.06790	0.000	Volts
1F	+5V Bus:	+2.035	+0.0312	0.000	Volts
20	+8.5V Bus:	+5.614	+0.0184	0.000	Volts
21	+10V Bus:	+7.650	+0.0250	0.000	Volts
22	BCR Set Point:	+3.7928	+1.0616	0.000	Counts
23	BCR Load Cur:	-0.0244	+0.00628	0.000	Amps
24	+8.5V Bus Cur:	+0.00412	+0.000773	0.000	Amps
25	+5V Bus Cur:	+0.02461	+0.00438	0.000	Amps
26	+X Array Cur:	-0.01614	+0.00232	0.000	Amps
27	-X Array Cur:	-0.01158	+0.00238	0.000	Amps
28	-Y Array Cur:	+0.00278	+0.00206	0.000	Amps
29	+Y Array Cur:	+0.00136	+0.00218	0.000	Amps
2A	-Z Array Cur:	+0.00370	+0.00209	0.000	Amps
2B	+Z Array Cur:	-0.00793	+0.00216	0.000	Amps
2C	Ext Power Cur:	-0.02000	+0.00250	0.000	Amps
2D	BCR Input Cur:	-0.00901	+0.00283	0.000	Amps
2E	BCR Output Cur:	+0.00663	+0.00344	0.000	Amps
2F	Bat 1 Temp:	+93.24	-0.5609	0.000	Deg. C
30	Bat 2 Temp:	+93.24	-0.5609	0.000	Deg. C
31	Baseplt Temp:	+93.24	-0.5609	0.000	Deg. C
32	PSK TX RF Out:	+0.1059	+0.00095	+0.0000834	Watts
33	RC PSK TX Out:	+0.0178	+0.00135	+0.0000833	Watts
34	PSK TX HPA Temp	+93.24	-0.5609	0.000	Deg. C
35	+Y Array Temp:	+93.24	-0.5609	0.000	Deg. C
36	RC PSK HPA Temp	+93.24	-0.5609	0.000	Deg. C
37	RC PSK BP Temp:	+93.24	-0.5609	0.000	Deg. C
38	+Z Array Temp:	+93.24	-0.5609	0.000	Deg. C
39	LU Bcn Temp A:	+93.24	-0.5609	0.000	* Deg. C
3A	LU Bcn Temp D:	+93.24	-0.5609	0.000	** Deg. C
3B	Coax Rly Stat:	+0.000	+1.0000	0.000	Counts
3C	Coax Rly Stat:	+0.000	+1.0000	0.000	Counts

Calibration equation: $Y = A + X(B + (X*C))$, where x is the channel data

LUSAT CW Telemetry

In mid-summer 1990 the CW telemetry was turned off to conserve power. It was turned back on in the fall of 1990, and off in late fall 1990. So expect an erratic schedule for CW telemetry on LUSAT. Figure 9.5 is an example of hand decoding the LUSAT CW telemetry. LUSAT has a low power SSB CW telemetry beacon on board. It operates on a nominal frequency of 437.127 MHz. The doppler shift will cause it to be received from 437.34 to 437.12 MHz during its pass - 22 kHz. It uses about 750 mW of power and transmits the data in a special compressed Morse code format. LUSAT uses the following format for the STATUS channel and 8 data channels:

E LUSAT HI HI NL 111 222 333 444 555 666 777 888

where :

E is the initialization character
LUSAT is the satellite identifier
HI HI is the introductory group to say the data is coming next
N is the EPROM version number. The program is repeated 7 times in the EPROM to provide redundancy. In case of damage to the program from radiation, the operating system can load the first OK version of the program to run. A number other than 1 indicates that some damage has occurred to the EPROM(Erasable/Programmable Read Only Memory).

L is the test result of the 6805 Ram (random access memory). If L = O(letter) the ram is OK. If L = E then an error has been detected.

111 through 888 are the compressed code raw decimal telemetry values, 111 = N1 through 888 = N8 as shown below.

Table 9.2 LUSAT CW telemetry calibration equations

CH# 1 = N1	+5 Regulated volts	636/N1	= volts
CH# 2 = N2	+10 volts Battery	0.064*N2	= volts
CH# 3 = N3	CW TX temperature	0.354(134.7-N3)	= degrees C
CH# 4 = N4	CW TX Power Output	(10.9+N4)^2/40.1	= mWatts
CH# 5 = N5	Temp. Box no. 4	0.356(136-N5)	= degrees C
CH# 6 = N6	+10 v Current	0.7*N6	= mA
CH# 7 = N7	Solar panel +Z volts	0.15*N7	= volts
CH# 8 = N8	Regulated +8.5 volts	0.056*N8	= volts

The compressed codes are only for the numeric data after the HI HI.

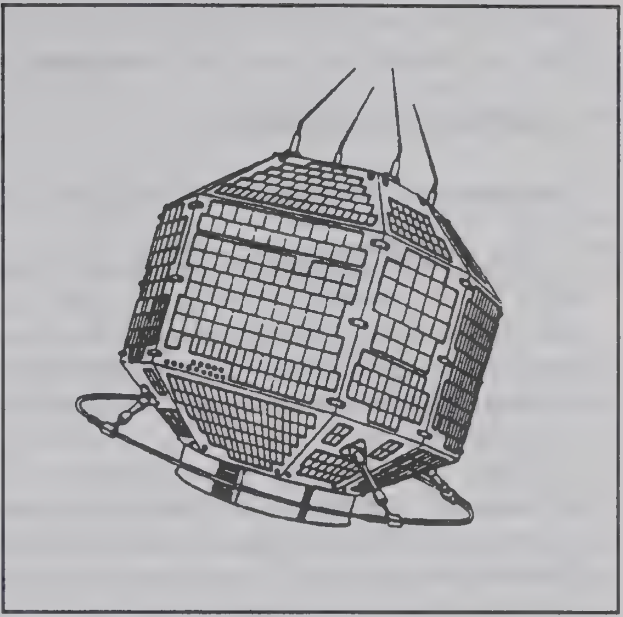
Table 9.3 LUSAT compressed Morse numeric codes

1:	.-	(A)	6:	-....	(6)
2:	..-	(U)	7:	-...	(B)
3:	...-	(V)	8:	-..	(D)
4:	....-	(4)	9:	-.	(N)
5:	.	(E)	0:	-^	(T)

Figure 9.5 example of hand decoding LUSAT CW telemetry
data captured 16 MAR 90 0344 UTC

```
E LUSAT HI HI AO AUN A6D AVU ADA AUV ABT TTA AEE

E LUSAT HI HI AO AUN A6D AVA ADT AVV ABA TTA AEE


                 111 222 333 444 555 666 777 888
E LUSAT HI HI AO AUN A6D AVU ADA AUV ABT TTA AEE
                 129 168 132 181 123 170 001 155

E LUSAT HI HI AO AUN A6D AVA ADT AVV ABA TTA AEE
                 129 168 131 180 122 171 001 155

CHANNEL #1  636/N1              636/129 -> 4.93 V       636/129 -> 4.93 V

CHANNEL #2  0.064*N2           .064/168 -> 10.75 V     .064/168 -> 10.75 V

CHANNEL #3  0.354(134.7-N3)    .354(2.7) -> .956 C     .354(3.7) -> 1.31 C

CHANNEL #4 (10.9+N4)2/40.1     36825.61/40.1-> 918mW   36442.8/40.1-> 908.8mW

CHANNEL #5 0.356(136-N5)       .356(13) -> 4.63 C      .356(12) -> 4.98 C

CHANNEL #6 0.7 * N6            .7(170) -> 119 mA       .7(171) -> 119.7 mA

CHANNEL #7 0.15*N7             .15(1) -> .15 V         .15(1) -> .15 V

CHANNEL #8 0.056*N8            .056(155) -> 8.68 V     .056(155) -> 8.68 V
```

FO-20



Names: Fuji-OSCAR 20, JAS-1b
Object #: 20480
International ID: 1990-013C
Launch: 7 FEB 1990
Period: 112 minutes
Increment: 28.1° west per orbit
Orbit: circular LEO
Altitude: avg 1300 km, perigee 910 km, apogee 1744 km
Transponder: Mode J, inverting transponder
Bandwidth: 100 kHz
Operating modes: Voice, Packet store and forward, Telemetry

Telemetry: JA - CW and PSK on 435.795 MHz @ 100 mW
JD - 1200 bps PSK, AX.25 on 435.912 MHz @ 1 watt

Sponsor: JAMSAT, JARL (AMSAT-Japan)

Telemetry equipment needed:
RCVR: 70 cm SSB receiver, 1200 bps PSK demodulator, TNC connected to PSK demodulator, computer/terminal, pre-amp very helpful,
Antenna: 70 cm circular polarized

Software: G3ZCZ's WHATS-UP v0.55 for JD telemetry
CWTLM.BAS by WA4SXM

The fall of 1990 saw FO-20 experiencing heat problems, notably in the battery compartment. This was due to a lack of eclipse time to cool the spacecraft. It has been determined by the FO-20 command team that operation of the transponder did not add to the heat problem, so the transponders are left on. This schedule is subject to change at any time, especially if the satellite is in distress.

FO-20 telemetry

Telemetry from FO-20 is available during both mode JA and mode JD. CW telemetry is sent one frame per minute on 435.795 MHz while the satellite is in mode JA. This data consists of 12 analog items and 38 status items. The CW data doesn't provide the resolution that the PSK data does. The limited data set of the CW telemetry is done to send the most important information, in the shortest length of time, and using the least amount of power. During mode JD, PSK packet telemetry frames are transmitted on 435.91 MHz. Packet frames are sent every two seconds while in telemetry mode and one frame per minute while in digital mode. Each PSK frame has 27 analog items and 29 status items. PSK telemetry provides more data with more resolution than the CW telemetry, and has error checking built-in. It is important to track the satellite closely to get consistent, valid telemetry data. What sounds good to the ear is not necessarily good for the PSK demodulator. A good signal to noise level is required for good data reception.

FO-20 mode JA telemetry

Equipment: 435 MHz antenna, 435 MHz CW receiver, pencil and pad, preamp recommended

FO-20 CW telemetry is sent about 20 wpm on the mode JA beacon frequency of 435.795 MHz. The reliability of the data is only as good as the operators' ability to copy code error-free. It is also the responsibility of the operator receiving the code to add the UTC date/time group to the data received. Copying CW telemetry with a decoding box requires constant attention to keep the box tuned, because the doppler shift is very quick.

Each CW telemetry frame begins with an initialization sequence of 'HI HI' and is followed by five groups of four data channels, see Figures 10.1 and 10.2. Each channel is made up of 3 digits. Telemetry values 1A through 3D are analog data, and values 4A through 5D are status values. The three digits for each channel value are composed of a group number and the data value.

Figure 10.1 FO-20 CW telemetry frame format:

```
HI HI 1A  1B  1C  1D
      2A  2B  3B  4B
      3A  3B  3C  3D
      4A  4B  4C  4D
      5A  5B  5C  5D
```

Figure 10.2 FO-20 CW telemetry frame, June 6,1990 :

```
HI HI 155 148 168 168
      285 284 242 262
      348 350 350 350
      407 437 410 437
      520 536 500 500
```

The first digit of each channel is the group number (1 - 5), the next two digits are the decimal data value. The data value must be calibrated to give the true value. This is done by substituting the data into the FO-20 CW calibration equation for that channel (See Table 10.1).

From Figure 10.2 notice that 155 was copied for channel 1A. The 1 in the first position tells us that the data is part of group number 1. The 55 in the second and third position are the decimal data value. Channel 1A is a measure of the total solar array current. Substituting the data value 55 into the equation for N yields:

19 * (N + 0.4) --> 19 * (55 + 0.4) --> 19 * 55.4 --> 1052.6 mA total array current

Figure 10.3 Hand decoded analog values for FO-20 CW telemetry

```
channel 1B  (38 * (48 - 50)) --> 38 * -2 --> -76 mA Battery discharge
channel 1C  (68 + 4) * .22 --> 72 * .22 --> 15.84 V battery voltage
channel 1D  (168 + 4) * 0.1 --> 17.2V Battery center voltage

channel 2A  (85 + 4) * 0.2 --> 17.8V Bus voltage
channel 2B  (80 + 4) * 0.062 --> 84 * 0.062 --> 5.2 V on the +5V Bus
channel 2C  2.0 * (42+4)^1.618 --> 2.0 * 490.16 --> 980mW mode JA output power
channel 2D  (62 + 4) / 50 --> 1.32V Calibration voltage

channel 3A  1.4 * (67 - 48) --> 1.4 * 19 --> 26.6 deg C Battery temperature
channel 3B  1.4 * (67 - 50) --> 1.4 * 17 --> 23.8 deg C baseplate #1 temperature
channel 3C  1.4 * (67 - 50) --> 1.4 * 17 --> 23.8 deg C baseplate #2 temperature
channel 3D  1.4 * (67 - 50) --> 1.4 * 17 --> 23.8 deg C baseplate #3 temperature
```

Telemetry values 4A through 5D provide the current status of 38 points in the satellite. Figure 10.4 has hand decoded examples of the FO-20 status points. These channels are also sent as 3 decimal digits. The first digit being the group number and the second and third as an octal (base 8, digits 0 - 37) value. You will never get a digit greater than 7 since this is base 8. Octal is used because it is an efficient way to send binary data. Essentially this means that these two digits represent 5 bits of data. To convert the digits to binary or their bit representation: take the second digit of the three, assign its 2 bit representation (since maximum value of this digit is 3, two bits are all that are required). Then take the third of the three digits and assign its three bit representation.Three bits are necessary to represent values between 4 and 7. There are only 38 different status values instead of the expected 40 because bits 0,1 of channel 4C and bits 0,1 of channel 5A are combined. See Appendix C for decimal, hex, octal, binary conversion table.

Octal	Binary	Octal	Binary
0	00 or 000	4	100
1	01 or 001	5	101
2	10 or 010	6	110
3	11 or 011	7	111

In another example 407 was copied for channel 4A, the 4 is the group number, the 07 is the octal representation of the 5 status points. Converting 07 octal to binary gives: 0 --> 00; 7 --> 111. These 5 bits are then combined and numbered 4 to 0, left to right.

```
 (MSB)   4 3   2 1 0   (LSB)
         0 0   1 1 1
```

Reading the digits left to right, the left most binary digit is called the most significant bit (MSB). The right most digit is the least significant bit (LSB). So the converted binary data for channel 4A is 000111. Next determine which binary status values these define.

Figure 10.4 FO-20 hand decoding of status points for CW telemetry

Chan	Bit	Description	1	0	Data	Result
4A	4	Beacon	PSK	CW	0	CW Beacon
4A	3	Eng. data #3	---	---	0	Eng. data
4A	2	Eng. data #1	---	---	1	Eng. data
4A	1	JTD power	ON	OFF	1	mode JD ON
4A	0	JTA Power	ON	OFF	1	mode JA ON
4B	4	Main relay	ON	OFF	1	Relay ON
4B	3	Battery logic	Tric	Full	1	Batt Tric
4B	2	Battery	Tric	Full	1	Batt Tric
4B	1	UVC level	1	2	1	UVC level 1
4B	0	UVC	ON	OFF	1	UVC ON
4C	4	Eng data #4	--	--	0	
4C	3	Eng data #3	--	--	1	
4C	2	PCU	Manual	Auto	0	PCU Auto
4C	1	PCU bit #2(MSB)			0	
4C	0	PCU bit #1(LSB)			0	
4D	4	Computer power	ON	OFF	1	uC power ON
4D	3	Memory bank #3	ON	OFF	1	Bank 3 ON
4D	2	Memory bank #2	ON	OFF	1	Bank 2 ON
4D	1	Memory bank #1	ON	OFF	1	Bank 1 ON
4D	0	Memory bank #0	ON	OFF	1	Bank 0 ON
5A	4	Eng. data #7	---	---	1	
5A	3	Eng. data #6	---	---	0	
5A	2	Eng. data #5	---	---	0	
5A	1	Memory select 2 (MSB)			0	
5A	0	Mwmory select 1 (LSB)			0	
5B	4	Solar panel #5	Lit	Dark	1	panel #1 Lit
5B	3	Solar panel #4	Lit	Dark	1	panel #2 Lit
5B	2	Solar panel #3	Lit	Dark	1	panel #3 Lit
5B	1	Solar panel #2	Lit	Dark	0	panel #4 Dark
5B	0	Solar panel #1	Lit	Dark	1	panel #5 Lit
5C	4	Eng. data #11	--	--	0	
5C	3	Eng. data #10	--	--	0	
5C	2	Eng. data #9	--	--	0	
5C	1	Eng. data #8	--	--	0	
5C	0	JTA CW Beacon	CPU	TLM	0	JTA TLM
5D	4	Eng. data #16	--	--	0	
5D	3	Eng. data #15	--	--	0	
5D	2	Eng. data #14	--	--	0	
5D	1	Eng. data #13	--	--	0	
5D	0	Eng. data #12	--	--	0	

Table 10.1 FO-20 CW Telemetry Calibration Equations (8/90)

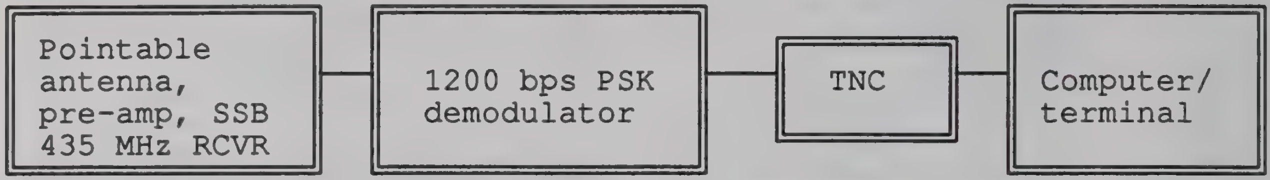
Channel	Description	Equation	Units
1A	Total Solar Array Current	19 * (N + 0.4)	mA
1B	Battery Charge/Discharge	38 * (N - 50)	mA
1C	Battery Voltage	(N + 4) * 0.22	V
1D	Battery Center Voltage	(N + 4) * 0.1	V
2A	Bus Voltage	(N + 4) * 0.2	V
2B	+5 V Regulator Voltage	(N + 4) * 0.062	V
2C	JTA Power Output	2.0 * (N + 4)^1.618	mW
2D	Calibration Voltage	(N + 4) / 50	V
3A	Battery Temperature	1.4 * (67 - N)	Deg C
3B	Baseplate Temperature #1	1.4 * (67 - N)	Deg C
3C	Baseplate Temperature #2	1.4 * (67 - N)	Deg C
3D	Baseplate Temperature #3	1.4 * (67 - N)	Deg C

FO-20 Binary Status Data

Channel	Bit	Description	1	0
4A	0	JTA Power	ON	OFF
4A	1	JTD power	ON	OFF
4A	2	Eng. data #1	---	---
4A	3	Eng. data #3	---	---
4A	4	Beacon	PSK	CW
4B	0	UVC	ON	OFF
4B	1	UVC level	1	2
4B	2	Battery	Trickle	Full
4B	3	Battery logic	Trickle	Full
4B	4	Main relay	ON	OFF
4C	0	PCU bit 1 (LSB)		
4C	1	PCU bit 2 (MSB)		
4C	2	PCU	Manual	Auto
4C	3	Eng. data #3	---	---
4C	4	Eng. data #4	---	---
4D	0	Memory bank #0	ON	OFF
4D	1	Memory bank #1	ON	OFF
4D	2	Memory bank #2	ON	OFF
4D	3	Memory bank #3	ON	OFF
4D	4	Computer power	ON	OFF
5A	0	Memory select bit 1 (LSB)		
5A	1	Memory select bit 2 (MSB)		
5A	2	Eng. data #5	---	---
5A	3	Eng. data #6	---	---
5A	4	Eng. data #7	---	---
5B	0	Solar panel #1	Lit	Dark
5B	1	Solar panel #2	Lit	Dark
5B	2	Solar panel #3	Lit	Dark
5B	3	Solar panel #4	Lit	Dark
5B	4	Solar panel #5	Lit	Dark
5C	0	JTA CW beacon	CPU	TLM
5C	1	Eng. data #8	---	---
5C	2	Eng. data #9	---	---
5C	3	Eng. data #10	---	---
5C	4	Eng. data #11	---	---
5D	0	Eng. data #12	---	---
5D	1	Eng. data #13	---	---
5D	2	Eng. data #14	---	---
5D	3	Eng. data #15	---	---
5D	4	Eng. data #16	---	---

FO-20 Mode JD Telemetry

Figure 10.5 FO-20 telemetry receiving station equipment connection diagram.



Capturing the telemetry

Setup a receiving station using the example in Figure 10.5. As FO-20 comes above the horizon, tune to get the strongest beacon signal. Then watching the PSK unit re-tune to get both a TUNE and LOCK indication on the PSK demodulator. It is a full time job to manually keep the PSK unit tuned and locked with the satellite signal. It is almost mandatory to have the PSK unit control the receiver frequency. Receiving telemetry from horizon to horizon requires a pointable antenna. The signal above 10-15 degrees elevation may be strong enough to receive on a stationary antenna, you decide how much of the telemetry you want to capture. The satellite moves rapidly, so it is necessary to track the satellite closely to maintain a good signal strength. Make sure that the TNC and computer are using the same baud rate, parity, data bits, and stop bits.

If you don't have decoding software you may capture the AX.25 data in a log file. Most terminal programs allow you to capture what is printed on the screen to a file. After storing the data you may print it out and begin the hand decoding. This is a nice exercise, but repetitious work is better left to a computer. There is sufficient information to try your hand at writing your own decoding program.

TAPR 1200 bps PSK modem switch settings:

MAN	means Manchester, not manual
USB/LSB	set the same as the receiver sideband selected
PSK ON	
JOINT/SPLIT	this doesn't matter for telemetry reception

FO-20 PSK telemetry format

The PSK telemetry frame begins with the satellite identification, the frame identifier and UTC date/time group on line 1. Four lines of telemetry data finish the frame. The data is sent in 4 lines of 10 channels each. Line 2 has channels 00 - 09, line 3 channels 10 - 19, line 3 channels 20 - 29, and channels 30 - 39 in line 5. Figure 10.6 displays the general PSK telemetry frame format. Data takes one of three forms: three decimal digits per channel(channels 00 - 26); three hexadecimal digits per channel (channels 27 - 29); and three binary digits (channels 30 - 39).

Figure 10.6 FO-20 PSK telemetry frame format:

```
JAS1b FI YY/MM/DD HH:MM:SS
xxx xxx xxx xxx xxx xxx xxx xxx xxx xxx
xxx xxx xxx xxx xxx xxx xxx xxx xxx xxx
xxx xxx xxx xxx xxx hhh hhh hhh hhh hhh
bbb bbb bbb bbb bbb bbb bbb bbb bbb bbb
```

The telemetry data is either realtime or stored data. If the frame identifier begins with 'R' it is realtime data, if an 'S' then stored data. The second character tells whether the data is in ASCII 'A' or Binary 'B' format. There are also 10 possible messages that can have the 'M' identifier.

The Frame Identifier defines the data type:

RA:	Realtime telemetry(ASCII)
RB:	Realtime telemetry(Binary)
SA:	Stored telemetry(ASCII)
SB:	Stored telemetry(Binary)
M0:	Message 0 of 10 possible
...	
M9:	Message 9

The telemetry data for channels 00 - 26 are three digit decimal data values that need to be substituted for N in the FO-20 PSK telemetry calibration equations. These equations are listed in Table 10.2. Each channel uses a specific formula to calibrate the received data to its actual value.

Telemetry data channels 27 - 29 are composed of three hexadecimal digits each. These values convey system status data. An explanation of converting hexadecimal data to decimal and binary is found in Appendix C, which also has a decimal, octal, hex, and binary conversion table. Each of the channels is broken down into 3 hex digits, referenced left to right a, b, & c. Using the data from Figure 10.7 we see that channel 29 has data 010. This equates 29a = 0, 29b = 1, and 29c = 0. Using Table 10.2, channel 29 contains error counts of Memory units 1, 2, & 3. Assigning the values to their respective memory unit channels: Memory unit #1 = 0 error counts, Memory unit #2 = 1 error count, and Memory unit #3 = 0 error counts.

Channels 30 - 39 contain binary status data. Each of the three digits is either 0 or 1. These binary values are referenced by the channel number, then left to right a, b, & c. Again using data from Figure 10.7 we see that channel 30 has a data value of 010. Breaking the data up into sub-channel values shows us that channel 30a = 0, channel 30b = 1, and channel 30c = 0. Again we use Table 10.2 to decode this data. We see from 30a that mode JA transmitter power is OFF, from 30b that mode JD transmitter power is ON, and that the mode JA beacon transmitter is sending CW telemetry. A complete frame decoding follows.

Figure 10.7 FO-20 telemetry data.

```
8J1JBS>BEACON:JAS1b RA 90/05/07 03:49:58
427 453 669 678 729 836 847 829 001 660
617 000 498 497 521 516 519 522 654 000
644 644 644 619 999 646 879 485 026 010
010 111 100 000 111 100^101 110 010 000
```

Figure 10.8 Hand decoded FO-20 Mode JD PSK telemetry

From the first line of the sample data, we see that this is realtime ASCII (RA) telemetry data from FO-20 (JAS1b) captured on MAY 7,1990 03:49:58 UTC.

```
Channel 00 -> 1.91 * (427 - 4) -> 807.9 mA generated by solar array
Channel 01 -> 3.81 * (453 - 508) -> -209.55 mA battery discharge current
Channel 02 -> 669 * 0.022 -> 14.718 V at the Battery
Channel 03 -> 678 * 0.009961 -> 6.753 V as the Battery center voltage
Channel 04 -> 729 * 0.02021 -> 14.73 V on the Bus
Channel 05 -> 836 * 0.00620 -> 5.18 V at the +5V regulator
Channel 06 -> 847 * -0.00620 -> -5.25 V at the -5V regulator
Channel 07 -> 829 * 0.0126 -> +10.44 V at the +10 V regulator
Channel 08 -> 5.1 * (001 - 158) -> -151.9 mW mode JA transmit power
Channel 09 -> 5.4 * (660 - 116) -> 2937.6 mW mode JD transmit power
Channel 10 -> 617 / 500 -> 1.234 V for the calibration voltage #2
Channel 11 -> 000 / 500 -> 0 V as offset voltage #1
Channel 12 -> 0.139 * (669 - 498) -> 23.8 Deg C for the battery temperature
Channel 13 -> 0.139 * (669 - 497) -> 23.9 Deg C for the mode JD XMTR temp
Channel 14 -> 0.139 * (669 - 521) -> 20.6 Deg C Baseplate #1 temperature
Channel 15 -> 0.139 * (669 - 516) -> 21.3 Deg C Baseplate #2 temperature
Channel 16 -> 0.139 * (669 - 519) -> 20.9 Deg C Baseplate #3 temperature
Channel 17 -> 0.139 * (669 - 522) -> 20.4 Deg C Baseplate #4 temperature
Channel 18 -> 654 / 500 -> 1.3 V for temperature #1 calibration
Channel 19 -> 000 / 500 -> 0 V for offset voltage #2
Channel 20 -> 0.38 * (644 - 685) -> -15.6 Deg C facet #1 temperature
Channel 21 -> 0.38 * (644 - 643) -> +0.4  Deg C facet #2 temperature
Channel 22 -> 0.38 * (644 - 646) -> -0.8  Deg C facet #3 temperature
Channel 23 -> 0.38 * (619 - 647) -> -10.6 Deg C facet #4 temperature
Channel 24 -> not assigned
Channel 25 -> 646 / 500 -> 1.292 V temperature calibration #2
Channel 26 -> 879 / 500 -> 1.758 V temperature calibration #3
Channel 27 spare channel
Channel 28a,b spare channel
Channel 28c -> 6 error counts in Memory Unit #0
Channel 29 -> 010 -> 0 error counts in Memory Unit #1, #3, 1 error found in
            Memory Unit #2
Channel 30 -> 010 -> JA XMIT OFF, JD XMIT ON, JA XMIT Beacon sending CW
Channel 31 -> 111 -> UVC ON, UVC Level 1, Main relay ON
Channel 32 -> 100 -> Engineering data #1 = 1, battery status FULL,
            battery logic FULL
Channel 33 -> 000 -> Engineering data #2 is 0, PCU status is 00
Channel 34 -> 111 -> Memory units #0, #1, & #2 are all ON
Channel 35 -> 100 -> Memory unit #3 is ON, Memory select is 00
Channel 36 -> 101 -> Engineering data #3 = 1, #4 = 0, Computer power is ON
Channel 37 -> 110 -> Engineering data #5 = 1, Solar panel #1 is illuminated,
            panel #2 dark
Channel 38 -> 010 -> Solar panel #3 is dark, panel #4 illuminated,panel #5 is
            dark
Channel 39 -> 000 -> Eng data #6 = 0, CW Beacon source = telemetry,
            Eng data #7 = 0
```

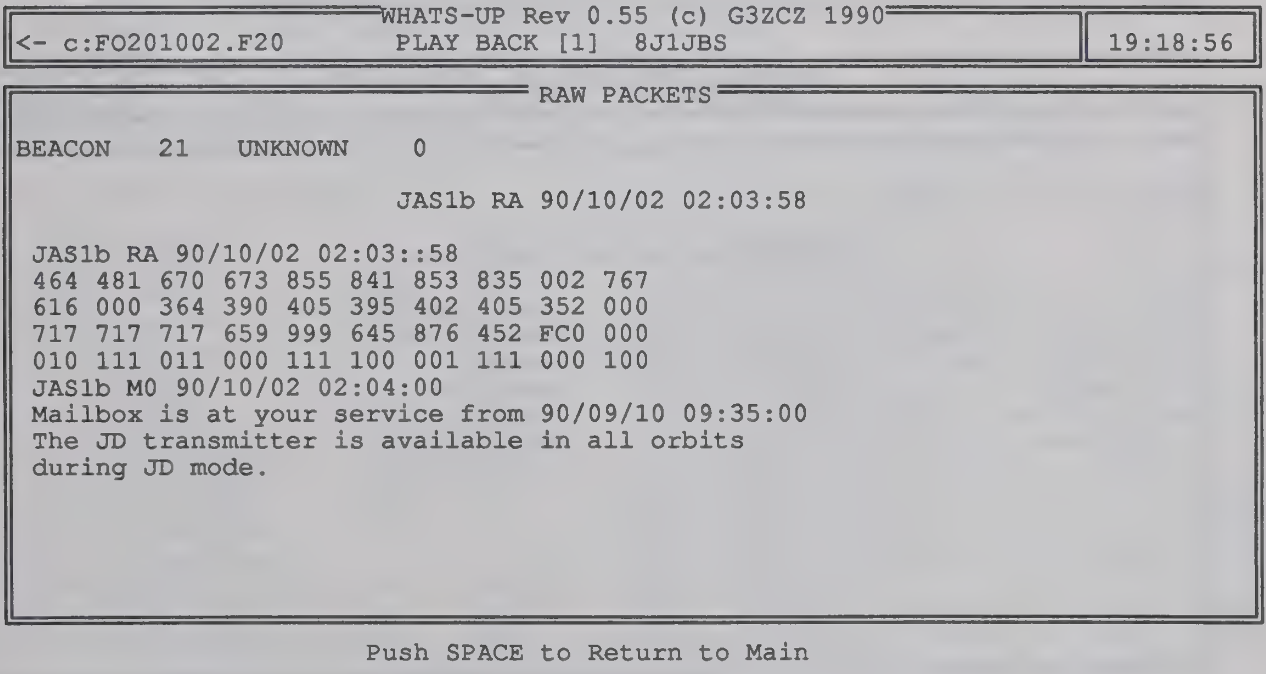
FO-20 Mode JD decoding software

Joe Kasser, W3/G3ZCZ has released v 0.55 of his WHATS-UP decoding program. Now it also includes the calibration equations for FO-20 as well as DOVE. The program will decode FO-20 telemetry both in realtime and playback data from a file. A very through manual and description of FO-20 telemetry are included. In playback mode the rate that the values update can be controlled. If the values update too rapidly press the <- cursor key immediately after pressing the "P" key for playback. Values that change from frame to frame are highlighted. Those that exceed limits that you can determine are also flagged. Three different screens are available to display the telemetry (SPACECRAFT TELEMETRY, STATUS WORDS, & RAW PACKETS). The menu to select one of these is invoked by pressing the "F3" key. Figures 10.9 - 10.11 show these screens. The default screen (SPACECRAFT TELEMETRY) is shown in Figure 10.10, the raw packet data is shown first in Figure 10.9 and the status words in Figure 10.11. The data displayed in Figure 10.11 was taken after the satellite began experiencing heat problems. Compare the battery temperatures from the telemetry received in Figure 10.4, Figure 10.8 and Figure 10.10.

Here is a conversion of the battery temperature from Figure 10.10 to Fahrenheit using the formula: (9/5 * C) + 32 = F.

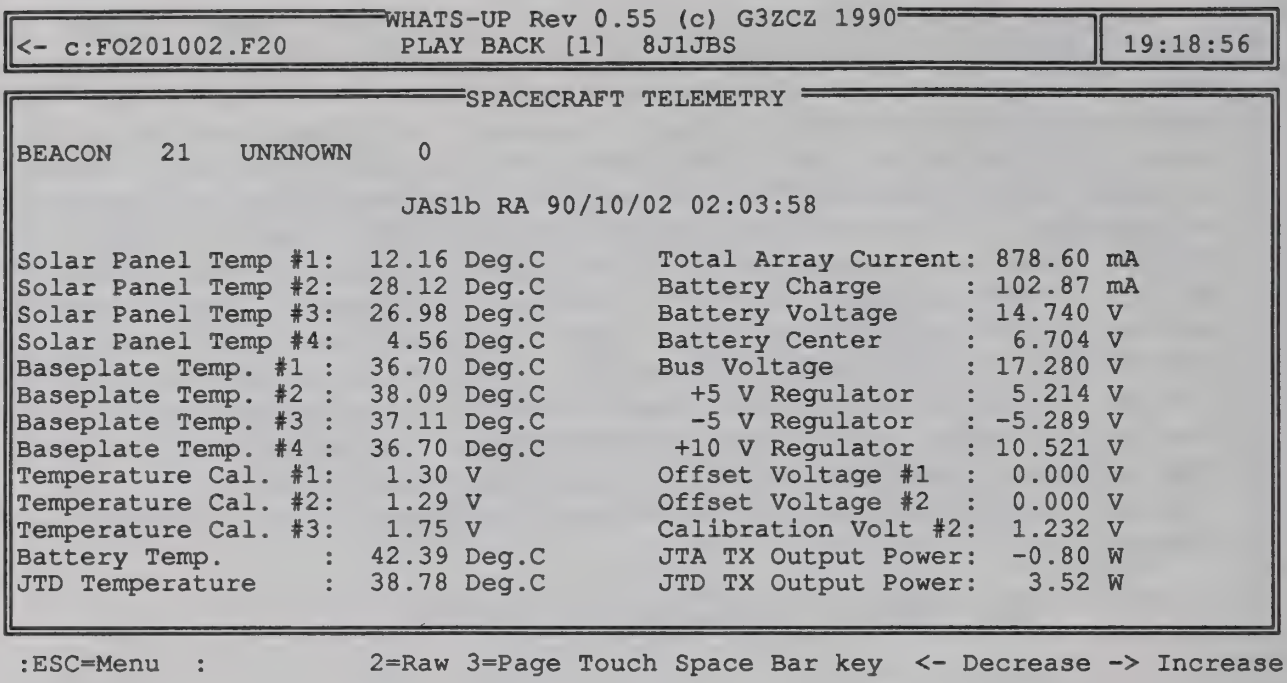
(9/5 * 42.39) -> 76.30 + 32 -> 108.3 deg F.

Figure 10.9 Data screen from G3ZCZ's WHATS-UP FO-20 decoding software.



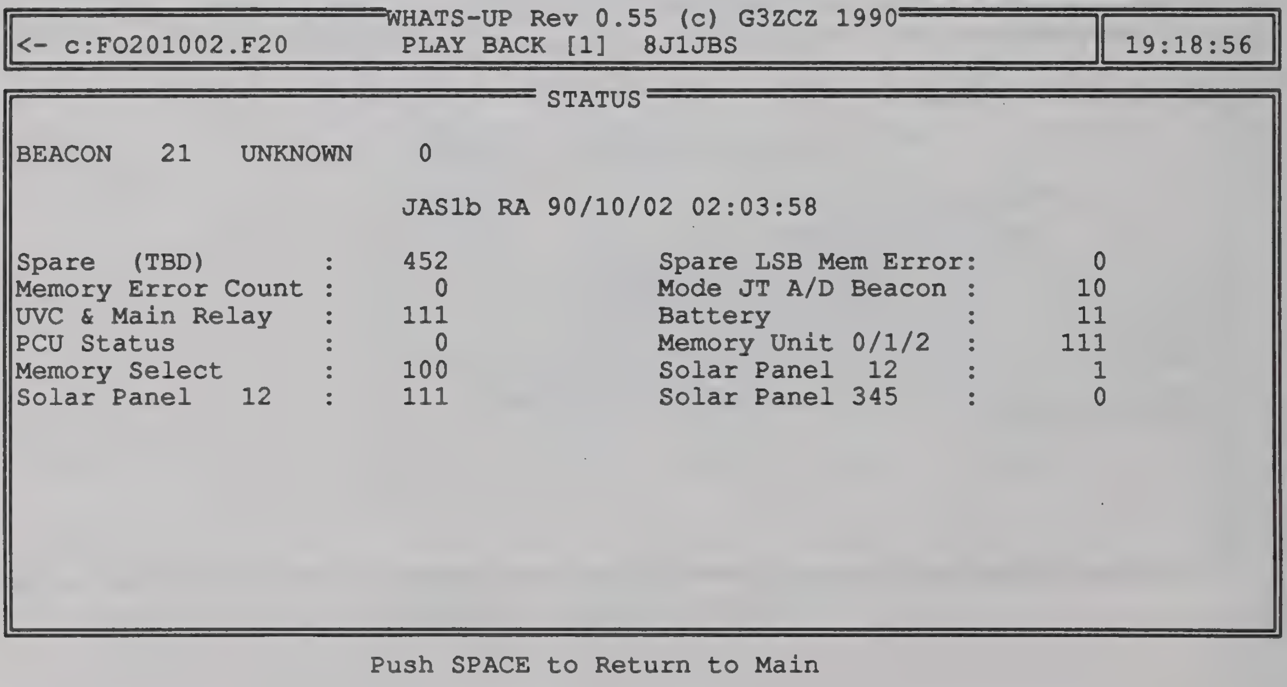
```
                         WHATS-UP Rev 0.55 (c) G3ZCZ 1990
<- c:FO201002.F20          PLAY BACK [1]  8J1JBS                    19:18:56

                                  RAW PACKETS

BEACON   21   UNKNOWN    0

                          JAS1b RA 90/10/02 02:03:58

 JAS1b RA 90/10/02 02:03::58
 464 481 670 673 855 841 853 835 002 767
 616 000 364 390 405 395 402 405 352 000
 717 717 717 659 999 645 876 452 FC0 000
 010 111 011 000 111 100 001 111 000 100
 JAS1b M0 90/10/02 02:04:00
 Mailbox is at your service from 90/09/10 09:35:00
 The JD transmitter is available in all orbits
 during JD mode.

                        Push SPACE to Return to Main
```

Figure 10.10 Default screen of G3ZCZ's WHATS-UP FO-20 decoding program, using data from Figure 10.9



```
                        WHATS-UP Rev 0.55 (c) G3ZCZ 1990
<- c:FO201002.F20        PLAY BACK [1]  8J1JBS                   19:18:56

                              SPACECRAFT TELEMETRY

BEACON   21   UNKNOWN    0

                         JAS1b RA 90/10/02 02:03:58

Solar Panel Temp #1:  12.16 Deg.C       Total Array Current: 878.60 mA
Solar Panel Temp #2:  28.12 Deg.C       Battery Charge     : 102.87 mA
Solar Panel Temp #3:  26.98 Deg.C       Battery Voltage    : 14.740 V
Solar Panel Temp #4:   4.56 Deg.C       Battery Center     :  6.704 V
Baseplate Temp. #1 :  36.70 Deg.C       Bus Voltage        : 17.280 V
Baseplate Temp. #2 :  38.09 Deg.C         +5 V Regulator   :  5.214 V
Baseplate Temp. #3 :  37.11 Deg.C         -5 V Regulator   : -5.289 V
Baseplate Temp. #4 :  36.70 Deg.C        +10 V Regulator   : 10.521 V
Temperature Cal. #1:   1.30 V           Offset Voltage #1  :  0.000 V
Temperature Cal. #2:   1.29 V           Offset Voltage #2  :  0.000 V
Temperature Cal. #3:   1.75 V           Calibration Volt #2:  1.232 V
Battery Temp.      :  42.39 Deg.C       JTA TX Output Power:  -0.80 W
JTD Temperature    :  38.78 Deg.C       JTD TX Output Power:   3.52 W

:ESC=Menu  :          2=Raw 3=Page Touch Space Bar key  <- Decrease -> Increase
```

Figure 10.11 WHATS-UP sample screen #3, FO-20 decoding software.



```
                        WHATS-UP Rev 0.55 (c) G3ZCZ 1990
<- c:FO201002.F20        PLAY BACK [1]  8J1JBS                   19:18:56

                                    STATUS

BEACON   21   UNKNOWN    0

                         JAS1b RA 90/10/02 02:03:58

Spare  (TBD)       :    452             Spare LSB Mem Error:       0
Memory Error Count :      0             Mode JT A/D Beacon :      10
UVC & Main Relay   :    111             Battery            :      11
PCU Status         :      0             Memory Unit 0/1/2  :     111
Memory Select      :    100             Solar Panel  12    :       1
Solar Panel   12   :    111             Solar Panel 345    :       0

                        Push SPACE to Return to Main
```

Table 10.2 FO-20 PSK Telemetry Calibration Equations (8/90)

Channel	Description	Equation	Units
00	Total Solar Array Current	1.91 * (N - 4)	mA
01	Battery Charge/Discharge	3.81 * (N - 508)	mA
02	Battery Voltage	N * 0.022	V
03	Battery Center Voltage	N * 0.009961	V
04	Bus Voltage	N * 0.02021	V
05	+5 V Regulator Voltage	N * 0.00620	V
06	-5 V Regulator Voltage	N * -0.00620	V
07	+10 V Regulator Voltage	N * 0.0126	V
08	JTA Power Output	5.1 * (N - 158)	mW
09	JTD Power Output	5.4 * (N - 116)	mW
10	Calibration Voltage #2	N / 500	V
11	Offset Voltage #1	N / 500	V
12	Battery Temperature	0.139 * (669 - N)	Deg C
13	JTD Temperature	0.139 * (669 - N)	Deg C
14	Baseplate Temperature #1	0.139 * (669 - N)	Deg C
15	Baseplate Temperature #2	0.139 * (669 - N)	Deg C
16	Baseplate Temperature #3	0.139 * (669 - N)	Deg C
17	Baseplate Temperature #4	0.139 * (669 - N)	Deg C
18	Temperature Calibration #1	N / 500	V
19	Offset Voltage #2	N / 500	V
20	Facet Temperature #1	0.38 * (N - 685)	Deg C
21	Facet Temperature #2	0.38 * (N - 643)	Deg C
22	Facet Temperature #3	0.38 * (N - 646)	Deg C
23	Facet Temperature #4	0.38 * (N - 647)	Deg C
24	----------------------------------		
25	Temperature Calibration #2	N / 500	V
26	Temperature Calibration #3	N / 500	V

FO-20 System Status Bytes in hexadecimal

27a	Spare
27b	Spare
27c	Spare
28a	Spare
28b	Spare
28c	Memory Unit #0 Error Count
29a	Memory Unit #1 Error Count
29b	Memory Unit #2 Error Count
29c	Memory Unit #3 Error Count

FO-20 Binary Status Data

	Description	1	0
30a	JTA Power	ON	OFF
30b	JTD Power	ON	OFF
30c	JTA Beacon	PSK	CW
31a	UVC Status	ON	OFF
31b	UVC Level	1	2
31c	Main Relay	ON	OFF
32a	Eng Data 1	--	--
32b	Battery Status	Tric	Full
32c	Battery Logic	Tric	Full
33a	Eng Data #2	--	--
33b	PCU Status lsb		
33c	PCU Status msb		
34a	Memory Unit #0	ON	OFF
34b	Memory Unit #1	ON	OFF
34c	Memory Unit #2	ON	OFF
35a	Memory Unit #3	ON	OFF
35b	Memory Select lsb		
35c	Memory Select msb		
36a	Eng Data #3	--	--
36b	Eng Data #4	--	--
36c	Computer Power	ON	OFF
37a	Eng Data #5	--	--
37b	Solar Panel #1	Lit	Dark
37c	Solar Panel #2	Lit	Dark
38a	Solar Panel #3	Lit	Dark
38b	Solar Panel #4	Lit	Dark
38c	Solar Panel #5	Lit	Dark
39a	Eng Data #6	--	--
39b	CW Beacon Source	CPU	TLM
39c	Eng Data #7	--	--

March 6, 1991

AO-21

Names: RS-14, Radio Sputnik 14
Object #: 21087
Launch: January 29, 1991
Period: 105 minutes
Increment: 26.3° west per orbit
Orbit: circular LEO
Altitude: avg 1000 km (621 miles)
Transponder: inverting, Mode B
Bandwidth: 80 kHz
Operating modes: CW, Voice, RUDAK
1200 bps BPSK,
400 bps BPSK,
2400 bps BPSK,
4800 bps BPSK,
9600 bps BPSK,
FSK (RTTY, SSTV, etc.),
FM modulated by DAC

No drawing available

Telemetry:

primary	
CW	145.822 MHz
1100 bps BPSK/FM	145.952 MHz
1200 " " AX.25	145.983 MHz
secondary	
CW	145.948 MHz
1100 bps BPSK/FM	145.838 MHz
1100 bps BPSK/FM	145.800 MHz

Sponsor: AMSAT-U (AMSAT-USSR), AMSAT-DL

Telemetry equipment needed:
VHF FM receiver for 2 M, pre-amp helpful, 1100 bps PSK demodulator, 1200 bps PSK demodulator, 400 bps PSK demodulator, TNC, computer/terminal

Software: CWTLM.BAS by WA4SXM

AO-21 is a separate amateur radio package aboard a Soviet geological research satellite. The transponders can be used for voice or CW communication. There are two beacon/transponder systems aboard but, only one of the beacon/transponders will be operational at any time.

The AO-21 beacon has three telemetry modes available but, no published schedule of when each mode will be active. The 1100 bps BPSK may seem unusual to many of us in the West, but there is a widely used personal computer in the USSR that has 1100 bps as a standard baud rate.

The AO-21 (RS-14) telemetry modes and beacon frequencies are:

Primary set

CW telemetry, 8 channels @ 145.822 MHz, 0.2 watts
1100 bps BPSK/FM, 30 channels @ 145.952 MHz, 0.4 watts
1200 bps BPSK AX.25, 30 channels @ 145.983 MHz, 3.0 watts, (like FO-20)

Secondary set

CW telemetry, 8 channels @ 145.948 MHz, 0.2 watts
1100 bps BPSK/FM, 30 channels @ 145.838 MHz, 0.4 watts
1100 bps BPSK/FM, 30 channels @ 145.800 MHz, 2.0 watts

AO-21 CW Telemetry

CW telemetry from AO-21 (FO-14) began very soon after separation from the launch vehicle. The format consists of 8 rows, each row containing four characters. The rows are designated row 0 - 7. Each of the characters in the row is labelled as either A, B, C, or D. These four characters in each row also form columns A - D. Rows 0 - 6 are for analog telemetry data, row 7 is the engineering calibration parameter.

Figure 11.1 AO-21 CW telemetry format

```
RS14 0A 0B 0C 0D
     1A 1B 1C 1D
     2A 2B 2C 2D
     3A 3B 3C 3D
     4A 4B 4C 4D
     5A 5B 5C 5D
     6A 6B 6C 6D
     7A 7B 7C 7D
```

Column A describes the system status, digits 6 or 2.
6 means general operating status
2 means command operating status

Column B identifies the channel numbers, 0 - 7.

Columns C & D are the decimal analog telemetry values.

Figure 11.2 AO-21 CW telemetry definitions and decoding/calibration equations.

Row	Parameter	Formula	Unit
0	Transponder power output	0.05 * N	Watt
1	Transponder PA temperature	N	Grad. C
2	+24 volts Regulated	N	Volts
3	+16 volts Regulated	N	Volts
4	+ 9 volts Regulated	N	Volts
5	+24 volts Regulated	N	Volts
6	Inside temperature	N	Grad. C
7	Service	N	-------

Figure 11.3 Sample AO-21 (RS-14) CW telemetry data 24 FEB 91 0302Z

```
received:    RS14 7059 7123 7224 7316 7410 7500 7600 77PP
             RS14 7059 7123 7224 7316 7410 7500 7600 77PP
             RS14 7048 7123 7224 7316 7410 7500 7600 77PP
             RS14 7059 7123 7224 7316 7410 7500 7600 77PP
             RS14 7059 7123 7224 7316 7410 7500 7600 77PP
             RS14 7057 7123 7224 7316 7410 7500 7600 77PP
             RS14 7059 7123 7224 7316 7410 7500 7600 77PP
             RS14 7059 7123 7224 7316 7410 7500 7600 77PP
```

As with most CW telemetry few channels change very often. This received data does not exactly fit the published decoding data. Updates will be made as soon as possible. From the data in Figure 11.3 it isn't clear whether the data for channels 5 and 6 are correct or not. The values for channels 1 - 7 are simply the last two digits of each group. Below are the converted power values:

2.95 Watts
2.95 Watts
2.40 Watts
2.95 Watts
2.95 Watts
2.85 Watts
2.95 Watts
2.95 Watts

Figure 11.4 Sample decoding of AO-21 CW data

```
received:    RS14 6080 6137 6224 6316 6409 2524 2632 2700

formatted:   RS14  6080
                   6137
                   6224
                   6316
                   6409
                   2524
                   2632
                   2700

decoded:     6080 --> general status channel 0  0.05 * 80 =  4 W Xponder power out
             6137 --> general status channel 1  37 Grad. C transponder PA temp
             6224 --> general status channel 2  24 volts 24 v regulated
             6316 --> general status channel 3  16 volts 16 v regulated
             6409 --> general status channel 4   9 volts  9 v regulated
             2524 --> command status channel 5  24 volts 24 v regulated
             2632 --> command status channel 6  32 Grad. C inside temp
             2700 --> command status channel 7  00
```

* * * * * * * * * * * * * * * * * *

AO-21 Digital Telemetry

Digital telemetry from AO-21 (RS-14) is primarily BPSK data sent at the 1100 bps rate, and occasionally sent at the 1200 bps rate using AX.25 we are equipped for here in the West. Both formats send 30 channels of hexadecimal data plus 2 channels that are constants. The digital data must be decoded by first substituting into a calibrating equations to get the value to substitute into the decoding equation. Table 11.1 has the published general digital telemetry definitions and decoding equations. Figure 11.6 shows a standard format for the received. The received data needs to be preprocessed by either of the formulas in Figure 1.7 before substituted for N in the equations in Table 11.1.

The data in Figure 11.5 was received in the 400 bps PSK format. There are more channels than in the published equations. Updates/Corrections will be made as soon as possible.

Figure 11.5 Sample AO-21 400 bps PSK telemetry received 24 Feb 1991 0500Z frequency 145.983 MHz

```
R  HI RUDAK

49 52 01 FF AF EC FE 3F CE 2B 99 50 00 10 C0 52
78 01 54 01 06 B7 00 00 00 03 00 03 7F 00 00 09
FC 19 27 79

R  HI RUDAK

39 52 01 FF 9C 3C FE 3F BC EB 99 50 00 10 C0 52
78 01 54 01 06 2C 00 00 00 03 00 03 7F 00 00 09
FD 04 34 79
```

Table 11.1 AO-21 digital telemetry definitions and decoding equations from ANS033.91

Line	Parameter	Formula	Unit	Hex-Format-Line
1	"Zero" of the comparator	0C		0000
2	Reference voltage	6D		0010
3	Transponder #1 HF ouptut pwr	0.2N^2	Watt	0020
4	Transponder #1 PA temperature	0.8*N	deg. C	0030
5	DC/DC converter temperature	0.8*N	deg. C	0040
6	+14 V Regulated	10*N	Volt	0050
7	+24 V Regulated	10*N	Voll	0060
8	+16 V Regulated	10*N	Volt	0070
9	+12 V Regulated	10*N	Volt	0080
10	+9 V Regulated	10*N	Volt	0090
11	+7.5 V Regulated	10*N	Volt	00A0
12	+5 V Regulated	10*N	Volt	00B0
13	+9 V Regulated (linear)	10*N	Volt	00C0
14	+9 V Regulated (digital)	10*N	Volt	00D0
15	Service	N	*	00E0
16	Service	N	*	00F0
17	Transponder #2 HF output pwr	0.2*N^2	Watt	0100
18	Transponder #2 PA temperature	0.8*N	deg. C	0110
19	+24 V Regulated	10*N	Volt	0120
20	+16 V Regulated	10*N	Volt	0130
21	+10 V Regulated	10*N	Volt	0140
22	+9 V Regulated	10*N	Volt	0150
23	+7.5 V Regulated	10*N	Volt	0160
24	Status command link 1	*	*	0170
25	Status command link 2	*	*	0180
26	Status command link	*	*	0190
27	Status command link	*	*	01A0
28	RPC +5V for Rudak-1	2.47*N	Volt	01B0
29	RPC +5V for Rudak-RTX	2.47*N	Volt	01C0
30	RPC +5V for Ramdisk	2.47*N	Volt	01D0
31	RPC +14V total supply current	627-289*N	mA	01E0
32	RPC module temperature	56.7*N-49.5	deg. C	01F0

Figure 11.6 Display on PC screen

```
0000 0C E6 0C E6 0C E6 0C E6 0C E6 0C E6 0C E6 0C E6
0010 6D E6 6D E6 6D E6 6D E6 6D E6 6D E6 6D E6 6D E6
0020 i  E6 i  E6 i  E6 i  E6 i  E6 i  E6 i  E6 i  E6
..................................................

01F0 j  E6 j  E6 j  E6 j  E6 j  E6 j  E6 j  E6 j  E6


i...j - the value of the parameter in the hex format,
        repeat  8 times

E6 - separation
```

Figure 11.7 Conversion formula to be used before the calibration equations

Conversion of tlm value to N

$$N = \frac{[(i...j)-0C]*1.16}{6D-0C}$$

N-table:

N	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.16	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6
i...j	0C	16	20	2A	34	3E	4B	52	5C	66	6D	70	7A	84	8E	98	A2	AC	B6	C0	CA	D4	BE	E6	F2	FA

or in decimal format:

$$N = \frac{[(i...j)-12]*1.16}{96}$$

i...j - the value of the parameter in the decimal format.

RPC - Rudak Power Conditioner

February 6, 1991

RS-12/13

Name(s): Radio Sputnik 12/13
Object #: 21089
Launch: February 5, 1991
Period: 105 minutes
Increment: 26.3° west per orbit
Orbit: circular LEO
Altitude: avg 1000 km (621 miles)
Transponder: inverting, Modes A, K, & T
Bandwidth: 40 kHz
Operating modes: CW, Voice

No drawing available

Telemetry:
RS-12 29.4543 or 145.9587
RS-13 29.5043 or 145.9083

Sponsor: AMSAT-U (AMSAT-USSR),

Telemetry equipment needed:
HF 10 M SSB receiver, pre-amp helpful

RS-12/13 was launched as a replacement for RS-10/11. In many ways it is much like RS-10/11. Both have two transponders aboard a civilian geological satellite. COSMOS 2123 is the name of the satellite containing RS-12/13. The same modes as RS-10/11 will be operated: A, K, and T. The orbit will be circular and polar with an inclination of 83 degrees.

It is anticipated that the telemetry format will be similar to that of RS-10/11. This manual will be updated as soon as possible after the information becomes available.

		RS-12	RS-13
MODE "A"	uplink	145.910 - 145.950	145.960 - 146.000
	downlink	29.410 - 29.450	29.460 - 29.500
	beacon	29.4081 (or 29.4543)	29.4582 (or 29.5043)
MODE "K"	uplink	21.210- 21.250	21.260 - 21.300
	downlink	29.410- 29.450	29.460 - 29.500
	beacon	29.4081 (or 29.4543)	29.4582 (or 29.5043)
MODE "T"	uplink	21.210 - 21.250	21.260 - 21.300
	downlink	145.910 - 145.950	145.960 - 146.000
	beacon	145.9125 (or 145.9587)	145.8622 (or 145.9083)
MODE "KA"	uplink	21.210 - 21.250 145.910 - 145.950	21.260 - 21.300 145.960 - 146.000
	downlink	29.410- 29.450	29.460 - 29.500
	beacon	29.4081 (or 29.4543)	29.4582 (or 29.5043)
MODE "KT"	uplink	21.210 - 21.250	21.260 - 21.300
	downlink	29.410 - 29.450 145.910 -145.950	29.460 - 29.500 145.960 - 146.000
	beacon	29.4081 (or 29.4543) 145.9125 (or 145.9587)	29.4582 (or 29.5043) 145.8622 (or 145.9083)

Autoanswer "Robot"

MODES	A; K; T; KA; KT	A; K; T; KA; KT
uplink	21.1291 and/or 145.8308	21.1385 and/or 145.8403
downlink	29.4543 and/or 145.9587	29.5043 and/or 145.9083

RS-12/13 TECHNICAL DATA

	RS-12	RS-13
DC POWER:		
All system OFF	4.6 W	3.5 W
All system ON (max. output)	35 W	25 W
RF OUTPUT POWER:		
Beacon and "Robot"(low/high)	0.45/1.2 W	0.45/1.2 W
Transponder TX (29 or 145)	about 8 W	about 8 W

ASCII

Table A-1. Hex - ASCII conversion table

Low nibble →

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
0	NUL	SOH	STX	ETS	EOT	ENQ	ACK	BEL	BS	HT	LF	VT	FF	CR	SO	SI
1	DLE	DC1	DC2	DC3	DC4	NAK	SYN	ETB	CAN	EM	SUB	ESC	FS	GS	RS	US
2	SP	!	"	#	$	%	&	'	(	)	*	+	,	-	.	/
3	0	1	2	3	4	5	6	7	8	9	:	;	<	=	>	?
4	@	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
5	P	Q	R	S	T	U	V	W	X	Y	Z	[	\	]	^	_
6	`	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o
7	p	q	r	s	t	u	v	w	x	y	z	{	|	}	~	DEL

↑
High nibble

ASCII is an acronym for American Standard Code for Information Interchange. It is a set of 127 7-bit characters used in digital communication. These include control characters, punctuation marks, numbers for base 10, and the upper and lowercase letters. These codes are transmitted as either serial or parallel data. Each country has a different set of symbols for letters, monetary units, and punctuation marks. This set of codes was designed for the American/English language set of symbols. These codes are what your computer, terminal, modem, LAN, printer translates into the characters presented on the screen or paper. The codes are defined as one byte hexadecimal values.
It is fairly common to distinguish ASCII characters by enclosing them within the greater than/less than symbols (< >).

To find the ASCII value of a character:

1) locate the character,
2) get the hex value for that row,
3) place the hex value for that column to the right of the value found in step 2.

Ex. uppercase G is in row 4, column 7, so ASCII value is 47h

To find the character associated with an ASCII value:

1) first locate the row of the first digit,
2) then find the column for the second digit,
3) the intersection is the ASCII character.

Ex. have ASCII code 06h, row 0, column 6 is the ACK character
have ASCII code 6Ah, row 6, column Ah is lowercase j

Control characters

These are the first 1Fh (32) characters of the ASCII set. There function is to do control operations. These operations include page formatting, user alert, and characters used in data protocols to define sections of the message packet.

Common page formatting characters are:

<NUL>	00h null, this is a space filler, usually meaning no data
<BS>	08h backspace, moves the cursor back to the left one character;
<HT>	09h horizontal tab, tabs to the right xx spaces;
<LF>	0Ah linefeed, goes to the next line down;
<VT>	0Bh vertical tab, go up a line;
<FF>	0Ch formfeed, goes to a new sheet of paper;
<CR>	0Dh carriage return,brings the cursor to the left margin;
<DEL>	7Fh delete, normally interpreted as a destructive backspace.

The <BEL> 07h, bell character, is the one that causes your computer, terminal, or printer to beep.

Transferring data at high speeds necessitates the use of error checking. Many of the control characters are used to enclose the data inside of packets. These packets contain information about the data, such as length, address, and error checking type. Control characters are used to distinguish fields of within the packet.

<SOH>	01h start of header;	<ETB>	17h end transmitted block;
<STX>	02h start of text;	<FS>	1Ch file separator;
<ETX>	03h end of text;	<GS>	1Dh group separator;
<EOT>	04h end of transmission;	<RS>	1Eh record separator;
<DLE>	10h data link escape;	<US>	1Fh unit separator;

The control characters are also used to regulate the transmissions between the devices.

<ENQ>	05h Enquiry, are you there?
<ACK>	06h Acknowledge, I received it OK.
<DC1>	11h Device control 1, CTRL/Q, resume transmission, software handshaking;
<DC3>	13h Device control 3, CTRL/S, stop transmission, software handshaking;
<NAK>	15h NOT Acknowledge, I did NOT receive the transmission OK.
<SYN>	16h Synchronize;
<ESC>	1Bh Escape, normally used as an exit function.

Special characters

Here are the names and uses for some of the unrecognized or seldom used ASCII characters.

<SP>	20h space, the blank character;
/	2Fh slash, solidus, division sign;
@	40h at sign;
[	5Bh left bracket, opening bracket;
\	5Ch backslash, reverse solidus, path separator;
^	5Eh caret, raise to a power, bitwise XOR (exclusive or);
_	5Fh underscore;
‘	60h grave accent;
{	7Bh left brace, opening brace;
|	7Ch vertical bar;
~	7Eh tilde.

March 5, 1991

Amateur Satellite Telemetry Beacon Frequencies

Frequency	Satellite	Mode(s)	Transmission type
29.360	RS-10	KA, K, A	CW @ 20 wpm
29.403	RS-10	KA, K, A	CW @ 20 wpm
29.407	RS-11	K	CW @ 20 wpm
29.4081	RS-12	A, K	CW
29.453	RS-11	KA, K, A	CW @ 20 wpm
29.4543	RS-12	A, K	CW
29.4582	RS-13	A, K	CW
29.5043	RS-13	A, K	CW
145.800	AO-21		1200 bps BPSK AX.25 (SSB) secondary
145.812	AO-13	B	400 bps PSK ASCII, 50 wpm RTTY (SSB), CW
145.822	AO-21		CW, primary
145.825	DO-17		1200 bps AFSK packet (FM)
145.825	UO-11		1200 bps AFSK ASCII (FM)
145.838	AO-21		1100 bps, BPSK (FM) secondary
145.848	AO-21		CW, secondary
145.857	RS-10	T	CW @ 20 wpm
145.8622	RS-13	T	CW
145.903	RS-10	KT	CW @ 20 wpm
145.907	RS-11	T	CW @ 20 wpm
145.9083	RS-13	T	CW
145.9125	RS-12	T	CW
145.952	AO-21		1100 bps, BPSK (FM) primary
145.953	RS-11	T	CW @ 20 wpm
145.9587	RS-12	T	CW
145.983	AO-21		1200 bps BPSK AX.25 (SSB) primary
435.025	UO-11		1200/4800 AFSK ASCII (FM)
435.070	UO-14	J	9600 bps AFSK ASCII (FM)
435.651	AO-13	JL	400 bps PSK ASCII, 50 wpm RTTY (SSB)
435.795	FO-20	JA	CW, 1200 bps PSK ASCII (SSB)
435.910	FO-20	JD	1200 bps PSK packet
437.025	AO-16	J	1200 bps PSK AX.25
437.050	AO-16	J	1200 bps PSK AX.25 (primary)
437.075	WO-18		1200 bps PSK AX.25
437.100	WO-18		1200 bps PSK AX.25 (primary)
437.125	LO-19		CW (** no set schedule **)
437.150	LO-19	J	1200 bps PSK AX.25 (primary)

March 4, 1991

Amateur Satellite Telemetry Beacons

SATELLITE	FREQ MHz	Mode	Transmission type
RS-10	29.360	KA, K, A	CW @ 20 wpm
	29.403	KA, K, A	CW @ 20 wpm
	145.857	T	CW @ 20 wpm
	145.903	KT	CW @ 20 wpm
RS-11	29.407	K	CW @ 20 wpm
	29.453	KA, K, A	CW @ 20 wpm
	145.907	T	CW @ 20 wpm
	145.953	T	CW @ 20 wpm
UO-11	145.825		1200 bps AFSK ASCII (FM)
	435.025		1200/4800 bps AFSK ASCII (FM)
AO-13	145.812	B	400 bps PSK ASCII(SSB)
	"	B	50 wpm RTTY (SSB)
	"	B	CW @ 10 wpm
	435.651	JL	400 bps PSK (SSB)
	"	JL	50 wpm RTTY (SSB)
UO-14	437.025	J	9600 bps FSK ASCII (FM)
AO-16	437.025	J	1200 bps PSK AX.25 (SSB)
	437.050	J	1200 bps PSK AX.25 (SSB) (primary), RC
DO-17	145.825		1200 bps AFSK AX.25 (FM)
WO-18	437.075	J	1200 bps PSK AX.25 (SSB)
	437.100	J	1200 bps PSK AX.25 (SSB) (primary), RC
LO-19	437.125		CW (** no set schedule **)
	437.125		1200 bps PSK AX.25 (SSB)
	437.150	J	1200 bps PSK AX.25 (SSB) (primary)
FO-20	435.795	JA	CW @ 20 wpm
	"	JA	1200 bps PSK ASCII (SSB)
	435.910	JD	1200 bps PSK ASCII (SSB)
AO-21	145.822		CW, primary
	145.952		1100 bps, BPSK (FM) primary
	145.983		1200 bps, BPSK AX.25 (SSB) primary
	145.800		1200 bps, BPSK AX.25 (SSB) secondary
	145.838		1100 bps, BPSK (FM) secondary
	145.848		CW, secondary
RS-12	29.4081	A, K, KA	CW
	29.4543	A, K, KA	CW
	145.9125	T, KT	CW
	145.9587	T, KT	CW
RS-13	29.4582	A, K, KA	CW
	29.5043	A, K, KA	CW
	145.8622	T, KT	CW
	145.9083	T, KT	CW

Appendix C

Number Bases, Conversion and Arithmetic

Hexadecimal

Just as base 10 has 10 distinct digits (0 - 9), base 16 needs 16 distinct digits. It uses the conventional 10 (0 - 9) and adds 6 new numbers A, B, C, D, E, F.

hex A = decimal 10
hex B = decimal 11
hex C = decimal 12
hex D = decimal 13
hex E = decimal 14
hex F = decimal 15.

As with base 10 after the last single digit you move to 2 digits, with a 0 in the ones location and a 1 in the 10's location. The same is true in hexadecimal counting, after the last single hex digt Fh comes 10h. Since it so easy to confuse which number base a number is representing, hexadecimal numbers are expressed with an 'h' suffix. Sometimes a $ is used in front of a number that identifies it as a hexadecimal number. Number 42h means hexadecimal number 42 which equals 66 decimal/base 10.

You will remember that 34 base 10 represents:

$$\begin{array}{ccc} 3 \times 10 & + & 4 \times 1 \\ 30 & + & 4 \longrightarrow 34 \end{array}$$

All number bases share the same principle.

To convert A4h to base 10:
1) multiply decimal equivalent of the left most hex digit x 16
2) add the decimal equivalent of right most digit.

(A = 10) so [10 x 16 = 160 base 10] + [1 x 4] = 164

so A4h = 164 base 10.

The largest 2 digit hex value is FFh which is equal to 255 base 10. An advantage of using hexadecimal is that with a 2 character base 16 number it is possible to describe 255(base 10) quantities in only 2 characters. This saves both transmitter power and memory needed to store the characters.

BCh --> [11 x 16 = 176] + [12 x 1] = 188 base 10

A hexadecimal, octal, decimal and binary conversion table follows the explanations.

Octal

Base 10 needs 10 distinct digits (0 - 9), and base 16 needs 16 distinct digits, octal or base 8 needs only 8 distinct digits (0 - 7). Notice that 7 is the largest single base 8 number. The next largest number is 10o. Often octal numbers are expressed with an 'o' suffix.
The number 36o represents octal number 36 which equals 30 decimal/base 10. Use the same approach as we did with the hexadecimal conversions.

1) multiply the left most octal digit x 8
2) multiply the right most digit by 1 and add to the product of step #1.

To convert 23o to base 10:
(2 x 8 = 16) + (3 x 1) = 19 base 10

The largest 2 digit octal value is 37 which is equal to 31 base 10. An advantage of using octal is that it is a multiple of base 2, so it is easy to convert between base 2 and octal.

Binary

As with the hexadecimal and octal explanations, the same principles apply to binary numbers. Binary is base 2, so there are only 2 digits (0 and 1). Computer and microprocessors do all their 'thinking' or operations in binary. This is why all these new numbers have surfaced lately and perplexed many of us that have grown up in a decimal world. So as not to confuse what number base a number represents, binary numbers append a 'b'. The binary number following 1b is 10b which is equal to 2 base 10. Now this can lead to some confusion as to whether the data is 10 binary or 10b hexadecimal. 'Generally' hexadecimal digits are uppercase letters and have an h appended. For the same reason hexadecimal is valuable because you can represent 255 quantities with only 2 characters, binary is very character intensive. For every power of 2 increase, another character must to be added to the left hand side of the digit.

Decimal	Binary	Hex
0	0	0
1	1	1
2	10	2
3	11	3
4	100	4
5	101	5
6	110	6
7	111	7

Decimal	Binary	Hex
8	1000	8
9	1001	9
10	1010	A
11	1011	B
12	1100	C
13	1101	D
14	1110	E
15	1111	F

So binary is one of the worst ways to send telemetry data, since it takes so many characters to represent so few quantities. Two raised to the 3rd power is 8, and 2 raised to the 7th power is 16. Now you should be able to see the reason for using octal and hexadecimal.

OR

A Boolean operation. If either or both of the operator is a 1, the result is a 1.

The rules:

$$\begin{array}{cccc} 0 & 0 & 1 & 1 \\ \underline{0} & \underline{1} & \underline{0} & \underline{1} \\ 0 & 1 & 1 & 1 \end{array} \qquad\qquad \begin{array}{c} 1010 \\ \underline{1110} \\ 1110 \end{array}$$

==

XOR eXclusive OR

This is another boolean (binary) operation.
Essentially 0 XOR 0 = 0, any combination of 0 XOR 1 = 1, and 1 XOR 1 = 0.
This is often used in checksum calculations.

Here are the rules:

$$\begin{array}{cccc} 0 & 0 & 1 & 1 \\ \underline{0} & \underline{1} & \underline{0} & \underline{1} \\ 0 & 1 & 1 & 0 \end{array} \qquad\qquad \begin{array}{c} 1010 \\ \underline{1110} \\ 0100 \end{array}$$

==

AND

Another boolean operation.

The rules:

$$\begin{array}{cccc} 0 & 0 & 1 & 1 \\ \underline{0} & \underline{1} & \underline{0} & \underline{1} \\ 0 & 0 & 0 & 1 \end{array} \qquad\qquad \begin{array}{c} 1010 \\ \underline{1110} \\ 1010 \end{array}$$

Decimal	Hex	Octal	Binary
0	0	0	00000000
1	1	1	00000001
2	2	2	00000010
3	3	3	00000011
4	4	4	00000100
5	5	5	00000101
6	6	6	00000110
7	7	7	00000111
8	8	10	00001000
9	9	11	00001001
10	A	12	00001010
11	B	13	00001011
12	C	14	00001100
13	D	15	00001101
14	E	16	00001110
15	F	17	00001111
16	10	20	00010000
17	11	21	00010001
18	12	22	00010010
19	13	23	00010011
20	14	24	00010100
21	15	25	00010101
22	16	26	00010110
23	17	27	00010111
24	18	30	00011000
25	19	31	00011001
26	1A	32	00011010
27	1B	33	00011011
28	1C	34	00011100
29	1D	35	00011101
30	1E	36	00011110
31	1F	37	00011111
32	20	40	00100000
33	21	41	00100001
34	22	42	00100010
35	23	43	00100011
36	24	44	00100100
37	25	45	00100101
38	26	46	00100110
39	27	47	00100111
40	28	50	00101000
41	29	51	00101001
42	2A	52	00101010
43	2B	53	00101011
44	2C	54	00101100
45	2D	55	00101101
46	2E	56	00101110
47	2F	57	00101111
48	30	60	00110000
49	31	61	00110001
50	32	62	00110010
51	33	63	00110011
52	34	64	00110100
53	35	65	00110101
54	36	66	00110110
55	37	67	00110111
56	38	70	00111000
57	39	71	00111001
58	3A	72	00111010
59	3B	73	00111011
60	3C	74	00111100
61	3D	75	00111101
62	3E	76	00111110
63	3F	77	00111111
64	40	100	01000000
65	41	101	01000001
66	42	102	01000010
67	43	103	01000011
68	44	104	01000100
69	45	105	01000101
70	46	106	01000110
71	47	107	01000111
72	48	110	01001000
73	49	111	01001001
74	4A	112	01001010
75	4B	113	01001011
76	4C	114	01001100
77	4D	115	01001101
78	4E	116	01001110
79	4F	117	01001111
80	50	120	01010000
81	51	121	01010001
82	52	122	01010010
83	53	123	01010011
84	54	124	01010100
85	55	125	01010101
86	56	126	01010110
87	57	127	01010111
88	58	130	01011000
89	59	131	01011001
90	5A	132	01011010
91	5B	133	01011011
92	5C	134	01011100
93	5D	135	01011101
94	5E	136	01011110
95	5F	137	01011111
96	60	140	01100000
97	61	141	01100001
98	62	142	01100010
99	63	143	01100011
100	64	144	01100100
101	65	145	01100101
102	66	146	01100110
103	67	147	01100111
104	68	150	01101000
105	69	151	01101001
106	6A	152	01101010
107	6B	153	01101011
108	6C	154	01101100
109	6D	155	01101101
110	6E	156	01101110
111	6F	157	01101111
112	70	160	01110000
113	71	161	01110001
114	72	162	01110010
115	73	163	01110011
116	74	164	01110100
117	75	165	01110101
118	76	166	01110110
119	77	167	01110111
120	78	170	01111000
121	79	171	01111001
122	7A	172	01111010
123	7B	173	01111011
124	7C	174	01111100
125	7D	175	01111101
126	7E	176	01111110
127	7F	177	01111111

Decimal	Hex	Octal	Binary
128	80	200	10000000
129	81	201	10000001
130	82	202	10000010
131	83	203	10000011
132	84	204	10000100
133	85	205	10000101
134	86	206	10000110
135	87	207	10000111
136	88	210	10001000
137	89	211	10001001
138	8A	212	10001010
139	8B	213	10001011
140	8C	214	10001100
141	8D	215	10001101
142	8E	216	10001110
143	8F	217	10001111
144	90	220	10010000
145	91	221	10010001
146	92	222	10010010
147	93	223	10010011
148	94	224	10010100
149	95	225	10010101
150	96	226	10010110
151	97	227	10010111
152	98	230	10011000
153	99	231	10011001
154	9A	232	10011010
155	9B	233	10011011
156	9C	234	10011100
157	9D	235	10011101
158	9E	236	10011110
159	9F	237	10011111
160	A0	240	10100000
161	A1	241	10100001
162	A2	242	10100010
163	A3	243	10100011
164	A4	244	10100100
165	A5	245	10100101
166	A6	246	10100110
167	A7	247	10100111
168	A8	250	10101000
169	A9	251	10101001
170	AA	252	10101010
171	AB	253	10101011
172	AC	254	10101100
173	AD	255	10101101
174	AE	256	10101110
175	AF	257	10101111
176	B0	260	10110000
177	B1	261	10110001
178	B2	262	10110010
179	B3	263	10110011
180	B4	264	10110100
181	B5	265	10110101
182	B6	266	10110110
183	B7	267	10110111
184	B8	270	10111000
185	B9	271	10111001
186	BA	272	10111010
187	BB	273	10111011
188	BC	274	10111100
189	BD	275	10111101
190	BE	276	10111110
191	BF	277	10111111
192	C0	300	11000000
193	C1	301	11000001
194	C2	302	11000010
195	C3	303	11000011
196	C4	304	11000100
197	C5	305	11000101
198	C6	306	11000110
199	C7	307	11000111
200	C8	310	11001000
201	C9	311	11001001
202	CA	312	11001010
203	CB	313	11001011
204	CC	314	11001100
205	CD	315	11001101
206	CE	316	11001110
207	CF	317	11001111
208	D0	320	11010000
209	D1	321	11010001
210	D2	322	11010010
211	D3	323	11010011
212	D4	324	11010100
213	D5	325	11010101
214	D6	326	11010110
215	D7	327	11010111
216	D8	330	11011000
217	D9	331	11011001
218	DA	332	11011010
219	DB	333	11011011
220	DC	334	11011100
221	DD	335	11011101
222	DE	336	11011110
223	DF	337	11011111
224	E0	340	11100000
225	E1	341	11100001
226	E2	342	11100010
227	E3	343	11100011
228	E4	344	11100100
229	E5	345	11100101
230	E6	346	11100110
231	E7	347	11100111
232	E8	350	11101000
233	E9	351	11101001
234	EA	352	11101010
235	EB	353	11101011
236	EC	354	11101100
237	ED	355	11101101
238	EE	356	11101110
239	EF	357	11101111
240	F0	360	11110000
241	F1	361	11110001
242	F2	362	11110010
243	F3	363	11110011
244	F4	364	11110100
245	F5	365	11110101
246	F6	366	11110110
247	F7	367	11110111
248	F8	370	11111000
249	F9	371	11111001
250	FA	372	11111010
251	FB	373	11111011
252	FC	374	11111100
253	FD	375	11111101
254	FE	376	11111110
255	FF	377	11111111

Appendix D

PART A WOD from UO-11 17 August 1990

```
00000000100200305B
01F9521521%21270DD
0201519 85500434B5
0209517398307520CA
021149451928652144
0219280517518521BF
022145451952038179
022952048752132394
0231518334514517FF
02395194863155219A
0241404518363521C7
024928951711952185
02514815205203474F
02595215215212925A
022151834851946866
0269180$03545"162
00n‘51941"9j215

02895d1521!21r2
029!5194345203 1"r
0995183365035219C
02A51)h4832052115
02A9343516369520&E
02B12875175195211F
02B9398518519434F2
02C152050152137034
02C95193895205001C
02D151942945252121
02D94755204095210F
02E127651750352116
02E931451751945922
02F15215215214044E
02F952044652049890
03015204355205210E
03095215194325210F
03115225215215220D
031952152152152206
0321522521521522FD
0329521521521522F6
0331521521521521EF
0339521521521521E7
0341521521521521DF
0349521521521521D7
0351521521521521CF
0359521521521522C6
0361521521521521BF
0369522521521521B6
0371521521521521AF
0379521521521521A7
03815225215215219E
038952252152152295
03915225215215218E
039952252152152186
03A15225215215227D
03A952252152152275
03B15225215215226D
03B952252152252264
03C15225215215225D
03C952252152252254
03D15225225225224B
03D952252152252244
03E15225225225223B
03E952252252252233
03F15225225225222B
03F952252252252223
04015225225225221A
040952252252252212
04115225225225220A
041952252252252202
0421522522522522FA
0429522522522522F2
0431522522522522EA
```

```
0439522522522522E2
0441522522522522DA
0449522522522522D2
0451522522522522CA
0459522522522522C2
0461522522522522BA
0469522522522522B2
0471522522522522AA
0479522522522522A2
048152152149852227
048925651643952158
049124251551845552
049952152152135356
04A15193915204300B
04A9518374461521EF
04B15175203615213B

00000000100200305B
0005516421181520CF
000D333514162520D7
001513551451752115
001D43351851922307
002551840751920945
002D517318482521AB
0035516465131520AB
003D27251535452173
0045229514517436DC
004D521520520143BA
0055518356519302CD
005D515327335517C6
00655025121075200B
006D213515447521AE
007532951751938558
007D52051452117465
008550231551746196
008D51036922550978
0095485518178521E1
009D22551646052152
00A53125175194249F
00AD52052152120794
00B551941452031098
00BD47331942150839
00C551851120952192
00CD3255173815210
00D524951551850758
00DD50’52052125035
00E55194185203284C
00ED467321429519F4
00F551850523752140
00FD347517380521AF
01052475165185210E
010D508520521270E3
0115519433520331F7
011D48731847452159
0125519501259521F0
012D38051837052154
0135245516519521DF
013D48152052131199
014D47832648952115
01555194872865210E
015D408518340521CB
01652575175195219C
016D4905205213105B
01755204575203326B
017D471340475521E6
01855105002885216B
018D4035183755206C
019528251751950959
019D5205185212951E
01A55194335193643B
01AD494360445521A3
01B551951427552131
```

```
01BD3545184035215C
01C531651751947727
01CD52152152127504
01D5519389511430F1
01DD513399338521C8
01E54955192775217F
01ED2775174925217C
01F5468519520349CA
01FD520467520329DC
020551736348452184
020D519513271521DD
0215373518418521CF
021D30051751952139
02255215215212859B
022D51838952042397
023551837237052159
023D5195192895218F
024529051749452108
024D3575175194755F
02555215215212915F
025D5194415203765B
0265517318451521A2
026D51951929352155
0275392518393521D6
027D29351751952147
02854475195203792A
028D52152152129523
02955183465194702C
029D5173744145214B
02A551151928152137
02AD29951749352198
02B53225175195069A
02BD5045205203693D
02C55194255204255F
02CD518393512521FC
02D5520499413521E5
02DD34551843552118
02E526751651851717
02ED44651952041427
02F55205005214244C
02FD51942752052128
0305521475513521D6
030D5215215085222B
03155225215215210A
031D52152152152202
0325521521521521FB
032D521521521521F3
0335522521521521EA
033D522521521521E2
0345521521521521DB
034D521521521521D3
0355521521521521CB
035D521521521521C3
0365521521521521BB
036D521521521521B3
0375521521521521AB
037D521521521521A3
03855225215215219A
038D52252152152192
039552252152152289
039D52252152152281
03A552252152152279
03AD52252152152271
03B552252152152269
03BD52252152252260
03C552252152252258
03CD52252152252250
03D552252252252247
03DD5225225225223F
03E552252252252237
03ED52252252210055
03F552252252252227
```

```
03FD5225225225221F
040552252252252216
040D5225225225220E
041552252252252206
041D522522522522FE
0425522522522522F6
042D522522522522EE
0435522522522522E6
043D522522522522DE
0445522522522522D6
044D522522522522CE
0455522522522522C6
045D522522522522BE
0465522522522522B6
046D522522522522AE
0475522522522522A6
047D5225225225229E
0485397519392521BF
048D202515517521CA
0495371518519384EC
049D520469521368F7
04A551935952051856
04AD519437389521FF

00000000100200305B
000351617724852 B$
00B450517134520E6
0013150514448520CD
001B351515518260B3
002351946352015697
002B51831951951321
0033515404179520C7
003B325513161520B9
00431195145175190B
004B466519520218A9
0053518407520253C6
005B516312461516B0
00631114701"252081
002B27651638352111
00732435155p46662
007B521%d152110469
00835093455193457C
008B497337"95506B9
009351851817352154
009B2795164035215D
00A323951551849210
00@B479520520254F3
00B3520463520261F4
00BB4753145055134E
00C3518472247521F6
00CB3875173135210E
00D321051651852178
00DB410j19520f093D
00E3520470521276A1
00EB4673174935218E
00F351p46275521A$
00F411518f115"154
01032295165185212E
010B451519520328EA
01135204845212805
011B49132149751333
01235184592975215E
012B44251830052103
013324551650852!E2
013B423519520369A9
0145520463520315AC
0143521511521266AD
014B4943444904078
0153518440308521B5
015B46250927252131
0163257515506521B1
016B4285195203736@
```

Part B PACSAT WOD data before BBS

```
PACSAT-1>AMSAT:
10/3/90 0450Z:Dumping WOD to correlate
TX power amp temp with power output,
Ch: 32, 2A, 37, 36, 34, 1E.  Dump will end
about 10/5/90.  See you all in Houston?   73, WD0E

PACSAT-1>WOD:
89ec08 27 88 00 a1 c8 ac 25
93ec08 27 87 00 a2 c9 ab 24
9dec08 27 8a 00 a3 c7 ac 25
a7ec08 27 89 00 a2 c7 ab 24
b1ec08 27 88 01 a3 ca ac 24
bbec08 27 87 00 a2 c8 ac 24
c5ec08 27 88 00 a2 c9 ac 25
cfec08 27 89 00 a4 c9 aa 24
d9ec08 27 87 00 a4 c8 ab 24
e3ec08 27 87 00 a2 ca b0 24
edec08 27 86 00 a1 ca b0 24
f7ec08 27 87 00 a4 ca b0 24
01ed08 27 87 00 a4 ca b0 24
0bed08 27 87 00 a4 ca ab 24
15ed08 27 87 00 a4 ca ac 24
1fed08 27 87 00 a1 ca b0 24
29ed08 27 88 00 a4 ca ac 24
33ed08 27 87 00 a4 ca b0 24
3ded08 27 87 01 a4 ca b0 24
47ed08 27 87 00 a4 ca b0 24
51ed08 27 87 00 a4 cb b0 24
5bed08 27 87 00 a4 cc b0 24
65ed08 27 87 00 a4 d0 b0 24
6fed08 27 87 00 a4 cc b0 24
79ed08 27 87 01 a4 d0 b0 24

PACSAT-1>TIME-1:PHT: uptime is 043/23:20:54.  Time is Fri Oct 05 02:50:25 1990

PACSAT-1>WOD
83ed08 27 87 00 a4 d0 b0 24
8ded08 27 87 01 a4 d0 ac 24
97ed08 27 87 00 a4 cc b0 24
a1ed08 27 89 00 a4 cc b0 24
abed08 27 87 00 a4 cc ad 24
b5ed08 27 87 00 a4 d0 b0 24
bfed08 27 87 00 a4 d0 b0 24
c9ed08 27 88 00 a4 cc b0 24
d3ed08 27 87 00 a6 d0 b0 24
dded08 27 87 00 a4 d0 b0 24
e7ed08 27 87 00 a4 d0 b0 24
f1ed08 27 87 00 a4 d0 b0 24
fbed08 27 87 00 a5 d0 b0 24
05ee08 27 87 00 a4 d0 b0 24
0fee08 27 87 00 a5 d0 b0 24
19ee08 27 86 00 a5 d0 b0 24
23ee08 27 88 00 a4 d0 b0 22
2dee08 27 87 00 a5 d0 b0 23
37ee08 27 87 00 a5 d0 b0 24
41ee08 27 87 00 a6 d0 b0 23
4bee08 27 87 00 a5 d0 b0 23
55ee08 27 87 00 a6 d0 ae 23
5fee08 27 86 00 a6 d0 b0 22
69ee08 27 87 00 a6 d0 b0 23
73ee08 27 87 00 a6 d0 b0 24

PACSAT-1>WOD
7dee08 27 87 00 a6 d0 b0 22
87ee08 27 86 00 a6 d0 b0 22
91ee08 27 86 00 a8 d0 b0 22
9bee08 27 87 00 a6 d0 b0 23
a5ee08 27 85 00 a6 d0 b0 22
afee08 27 87 00 a5 d0 b0 23
b9ee08 27 87 00 a6 d0 b0 52
c3ee08 27 87 00 a6 d0 af ff
cdee08 27 87 00 a7 d0 b0 ff
d7ee08 27 87 00 a6 d0 b0 ff
e1ee08 27 86 00 a7 d0 b0 ff
ebee08 27 88 00 a6 d0 b0 ff
f5ee08 27 86 01 a7 d0 b0 ff
ffee08 27 89 1e a6 d0 b0 b4
09ef08 27 89 1a a7 ca b0 bc
13ef08 27 8a 15 a7 c9 b0 ba
```

Part C Sample AO-16 TRACE data from TNC after the BBS operational, edited

```
000: AE847282 9CA2E0A0 8286A682 A87922F0  WB9ANQpPACSAT<.x  ..r..........y".
010: FD00AA55 0100044C 0C000002 00083237  ~.U*...&........  ...U...L......27
020: 63633537 65310300 03202020 04000466  11..2..........3  cc57e1...   ...f
030: 07000005 00040AFD CB270600 04D364CC  .......~e....i2f  .........'....d.
040: 27120004 4358CC27 07000100 08000100  ....!,f.........  '...CX.'........
050: 090002D9 440A0002 9F1E0B00 02AC0010  ...1"...O....V..  ....D...........
060: 00046B7A 31621100 064B5A31 42202013  ..5=.1...%-.!...  ..kz1b...KZ1B  .
070: 00010114 00067762 39616E71 15000620  ......;1.078....  ......wb9anq...
080: 20202020 20160004 00000000 17000443  ...............!       .........C
090: 9ED12718 00010019 00010226 00096272  Oh............19  ..'........&..br
0A0: 7563652E 7A697022 00066574 63657463  :12.=48...2:12:1  uce.zip"..etcetc
0B0: 23000870 672C7265 706C7900 0000504B  ...83.9286<...(%  #..pg,reply...PK
0C0: 03040A00 00000600 936C5B16 1DB1702A  ........I6-..X8.  .........l[...p*
0D0: 4E060000 F20A0000 05000000 42525543  '...y.......!)*!  N...........BRUC
0E0: 450D0201 12231415 36376889 9ADB3C05  ".........4DMm..  E....#..67h...<.
0F0: 06121344 C5F696F7 91A60529 546EDDB1  ..."b{K{HS..*7nX  ...D.......)Tn..
100: 655DBA74 D9502148 10C14F15 6D58B7    2.]:l(.$.`'.6,[   e].t.P!H..O.mX.
PACSAT-12>WB9ANQ:

000: A8929A8A 404002A0 8286A682 A80303F0  TIME  .PACSAT..x  ....@@..........
010: 5048543A 20757074 696D6520 69732030  ($*..:8:462.49..  PHT: uptime is 0
020: 33352F32 303A3230 3A34392E 20205469  ..............*4  35/20:20:49.  Ti
030: 6D652069 73205468 75204665 62203238  62.49.*4:.#21...  me is Thu Feb 28
040: 2030323A 34373A33 39203139 39310D20  ................   02:47:39 1991.
PACSAT-1>TIME-1:PHT: uptime is 035/20:20:49.  Time is Thu Feb 28 02:47:39 1991

000: 829AA682 A84000A0 8286A682 A80303F0  AMSAT .PACSAT..x  .....@..........
010: 322D3236 2D39310D 0D414F2D 31362069  ......... '....4  2-26-91..AO-16 i
020: 7320696E 20457870 6572696D 656E746F  9.47."<8294627:7  s in Experimento
030: 72204D6F 64652075 6E74696C 2061626F  9.&722.:7:46.017  r Mode until abo
040: 75742030 3530305A 206F6E0D 322D3238  ::.....-.77.....  ut 0500Z on.2-28
050: 2D39312E 20205468 65207261 69736564  ......*42.904922  -91.  The raised
060: 20434F53 494E4520 7472616E 736D6974  .!')$'".:907964:   COSINE transmit
070: 74657220 6973206F 6E202834 33372E30  :29.49.77.......  ter is on (437.0
080: 3530292C 0D616E64 20746865 20532D62  .....072.:42.).1  50),.and the S-b
090: 616E6420 7472616E 736D6974 74657220  072.:907964::29.  and transmitter
0A0: 6973206F 6E2E2020 506C6561 73652073  49.77...(62092.9  is on.  Please s
0B0: 656E6420 7265706F 7274730D 6F6E2074  272.92879:9.77.:  end reports.on t
0C0: 68652065 61736520 6F662063 6F707920  42.2092.73.178<.  he ease of copy
0D0: 6F662074 686520                      73.:42.           of the
PACSAT-1>AMSAT:2-26-91

AO-16 is in Experimentor Mode until about 0500Z on
2-28-91.  The raised COSINE transmitter is on (437.050),
and the S-band transmitter is on.  Please send reports
on the ease of copy of the

000: A6A882A8 AAA600A0 8286A682 A80303F0  STATUS.PACSAT..x  ................
010: 4B6FCC27 8000001E B0187701 00000000  %7f.@...X.;.....  Ko.'......w.....
020: 06083C05 00FB0000                    .....}..          ..<.....
PACSAT-1>STATUS:

000: 8484A6A8 82A800A0 8286A682 A81903F0  BBSTAT.PACSAT..x  ................
010: 46554C4C 20412020 203A2057 4239414E  #*&&. .....+!. '  FULL A   : WB9AN
020: 51204B38 544C2020 20574231 48425520  (.%.*&...+!.$!*.  Q K8TL   WB1HBU
030: 4E38414D 202020                      '. &...           N8AM
PACSAT-12>BBSTAT:FULL A   : WB9ANQ K8TL   WB1HBU N8AM

000: AE847282 9CA2E0A0 8286A682 A87920F0  WB9ANQpPACSAT<.x  ..r..........y .
010: 7B00B508 CEABCE19 A59C0C23 DC484E3A  =.Z.gUg.RN..n$'.  {..........#.HN:
020: 768E82D0 6F380E0B 0CD5C566 8390E7B2  ;GAh7....jb3AHsY  v...o8.....f....
030: 15515574 AFA9BF3D AD9E080E 54215128  .(*:WT_.VO..*.(.  .QUt...=....T!Q(
040: F613DE1A 504B0102 0A000A00 00000600  {.o.(%..........  ....PK..........
050: 936C5B16 1DB1702A 4E060000 F20A0000  I6-..X8.'...y...  .l[...p*N.......
060: 05000000 00000000 01002000 00000000  ................  .......... .....
070: 00004252 55434550 4B050600 00000001  ..!)*!"(%.......  ..BRUCEPK.......
080: 00010033 00000071 06000000 00        .......8.....     ...3...q.....
PACSAT-12>WB9ANQ:

000: AE846290 84AAE6A0 8286A682 A8794CF0  WB1HBUsPACSAT<&x  ..b..........yL.
010: 0001                                 ..                ..
PACSAT-12>WB1HBU-3:

000: 98A6A882 A84000A0 8286A682 A80303F0  LSTAT .PACSAT..x  .....@..........
010: 4920503A 30783135 4344206F 3A30206C  $.(..<..!".7...6  I P:0x15CD o:0 l
020: 3A313535 3820663A 31353538 2C20643A  ......3.......2.  :1558 f:1558, d:
030: 31207374 3A350D                      ..9:...           1 st:5.
PACSAT-1>LSTAT:I P:0x15CD o:0 l:1558 f:1558, d:1 st:5
```

```
000: 8484A6A8 82A800A0 8286A682 A81903F0  BBSTAT.PACSAT..x  ................
010: 4F70656E 20412020 203A204B 38544C20  '827. ......%.*&.  Open A   : K8TL
020: 20205742 31484255 204E3841 4D202020  ..+!.$!*.'. &...    WB1HBU N8AM
PACSAT-12>BBSTAT:Open A   : K8TL   WB1HBU N8AM

000: 9C70829A 4040E0A0 8286A682 A8798AF0  N8AM  pPACSAT<Ex  .p..@@.......y..
010: FD004131 4F475A12 0004F3C1 C3271300  ~. .'#-...y'a...  ..A1OGZ......'..
020: 01001400 066A6136 66746C15 00062020  .....50.3:6.....  .....ja6ftl...
030: 20202020 16000400 00000017 0004F307  ..............y.     ...........
040: C9271800 01001900 01002200 174E6F77  d.............'7;  .'........"..Now
050: 20492074 72696564 20504531 43484C2D  .$.:9422.(".!$&.   I tried PE1CHL-
060: 6E65742E 26000874 6F6A6136 66746C00  72:....:750.3:6.  net.&..toja6ftl.
070: 0000AA55 010004DA 0B000002 00083237  ..U*...m........  ...U..........27
080: 63336331 66390300 03202020 04000441  1.1.3..........   c3c1f9...    ...A
090: 01000005 00048930 C4270600 043DA7C5  ......D.b.....Sb  .......0.'...=..
0A0: 27070001 00080001 00090002 192B0A00  ................  '............+..
0B0: 02061F0B 0002B300 1000066A 61316F67  ......Y....50.73  ...........jalog
0C0: 7A110006 4A41314F 475A1200 0410C2C3  =...% .'#-.....aa  z...JA1OGZ......
0D0: 27130001 02140006 6A613666 746C1500  ........50.3:6..  '.......ja6ftl..
0E0: 06202020 20202016 00040000 00001700  ................  .      .........
0F0: 041008C9 27180001 00190001 00220017  ...d............  ....'........"..
100: 4E6F7720 49207472 69656420 504531    '7;.$.:9422.(".   Now I tried PE1
PACSAT-12>N8AM: A1OGZ ┴├'ja6ftl               ▛'"Now  I  tried  PE1CHL-net.&^Htoja6ftl U┌^H27c3c1f9
Aë0─'=º┼'^H     +
|jalogzJA1OGZ┬├'ja6ftl       ^H▛'"Now I tried PE1

000: 8484A6A8 82A800A0 8286A682 A81903F0  BBSTAT.PACSAT..x  ................
010: 46554C4C 20412020 203A2057 4239414E  #*&&. .....+!. '  FULL A   : WB9AN
020: 51204B38 544C2020 20574231 48425520  (.%.*&...+!.$!*.  Q K8TL   WB1HBU
030: 4E38414D 202020                      '. &...           N8AM
PACSAT-12>BBSTAT:FULL A   : WB9ANQ K8TL   WB1HBU N8AM

000: AE847282 9CA2E0A0 8286A682 A87922F0  WB9ANQpPACSAT<.x  ..r..........y".
010: FD00AA55 01000447 0C000002 00083237  ~.U*...#........  ...U...G......27
020: 63623364 30650300 03202020 040004C3  11.2.2.........a  cb3d0e...    ....
030: 01000005 000437EA C9270600 042D6ACC  .......ud.....5f  ......7..'...-j.
040: 27070001 00080001 00090002 B94C0A00  .............\&..  '............L..
050: 02AF260B 0002C800 10000457 44304511  .W....d....+".".  ..&.........WD0E.
060: 00065744 30452020 12000424 3DCB2713  ..+".".......e..  ..WD0E  ...$=.'.
070: 00010814 0003414C 4C150006 20202020  ...... &&.......  ......ALL...
080: 20201600 04000000 00170004 2483D027  ..............Ah.    ..........$..'
090: 18000100 19000100 26000670 61636578  ............8012<  .........&..pacex
0A0: 70220011 414F2D31 3620696E 20455850  8... '....47.",(  p"..AO-16 in EXP
0B0: 206D6F64 6523001F 65787065 72696D65  .6722...2<829462   mode#..experime
0C0: 6E746F72 206D6F64 65207261 69736564  7:79.6722.904922  ntor mode raised
0D0: 20636F73 69676E00 0000322D 32362D39  .179437.........   cosign...2-26-9
0E0: 310D0A0D 0A414F2D 31362069 7320696E  ..... '....49.47  1....AO-16 is in
0F0: 20457870 6572696D 656E746F 72204D6F  ."<8294627:79.&7   Experimentor Mo
100: 64652075 6E74696C 2061626F 757420    22.:7:46.017::.   de until about
PACSAT-12>WB9ANQ: cosign2-26-91

AO-16 is in Experimentor Mode until about

000: AE847282 9CA2E0A0 8286A682 A87924F0  WB9ANQpPACSAT<.x  ..r..........y$.
010: C6003035 30305A20 6F6E0D0A 322D3237  c.....-.77......  ..0500Z on..2-27
020: 2D39312E 20205468 65207261 69736564  .......*42.904922  -91.  The raised
030: 20434F53 494E4520 7472616E 736D6974  .!')$'".:907964:   COSINE transmit
040: 74657220 6973206F 6E202834 33372E30  :29.49.77.......  ter is on (437.0
050: 3530292C 0D0A616E 64207468 6520532D  ......072.:42.).  50),..and the S-
060: 62616E64 20747261 6E736D69 74746572  1072.:907964::29  band transmitter
070: 20697320 6F6E2E20 20506C65 61736520  .49.77...(62092.   is on.  Please
080: 73656E64 20726570 6F727473 0D0A6F6E  9272.92879:9..77  send reports..on
090: 20746865 20656173 65206F66 20636F70  .:42.2092.73.178   the ease of cop
0A0: 79206F66 20746865 73652074 72616E73  <.73.:4292.:9079  y of these trans
0B0: 6D697474 65727320 746F2057 4239414E  64::299.:7.+!. '  mitters to WB9AN
0C0: 51206F72 0D0A5744 30452E20 2037332C  (.79..+".".......  Q or..WD0E.  73,
0D0: 20574430 450D0A1A                    .+".".."...          WD0E...
PACSAT-12>WB9ANQ:▛0500Z on

2-27-91.  The raised COSINE transmitter is on (437.050),

and the S-band transmitter is on.  Please send reports

on the ease of copy of these transmitters to WB9ANQ or

WD0E.  73, WD0E
```

```
000: A8929A8A 404002A0 8286A682 A80303F0  TIME  .PACSAT..x  ....@@..........
010: 5048543A 20757074 696D6520 69732030  ($*..:8:462.49..  PHT: uptime is 0
020: 33352F32 303A3231 3A34392E 20205469  ..............*4  35/20:21:49.  Ti
030: 6D652069 73205468 75204665 62203238  62.49.*4:.#21...  me is Thu Feb 28
040: 2030323A 34383A33 39203139 39310D20  ................   02:48:39 1991.
PACSAT-1>TIME-1:PHT: uptime is 035/20:21:49.  Time is Thu Feb 28 02:48:39 1991

000: 829AA682 A84000A0 8286A682 A80303F0  AMSAT .PACSAT..x  .....@..........
010: 322D3236 2D39310D 0D414F2D 31362069  ......... '....4  2-26-91..AO-16 i
020: 7320696E 20457870 6572696D 656E746F  9.47."<8294627:7  s in Experimento
030: 72204D6F 64652075 6E74696C 2061626F  9.&722.:7:46.017  r Mode until abo
040: 75742030 3530305A 206F6E0D 322D3238  ::.....-.77.....  ut 0500Z on.2-28
050: 2D39312E 20205468 65207261 69736564  ......*42.904922  -91.  The raised
060: 20434F53 494E4520 7472616E 736D6974  .!')$'".:907964:   COSINE transmit
070: 74657220 6973206F 6E202834 33372E30  :29.49.77.......  ter is on (437.0
080: 3530292C 0D616E64 20746865 20532D62  .....072.:42.).1  50),.and the S-b
090: 616E6420 7472616E 736D6974 74657220  072.:907964::29.  and transmitter
0A0: 6973206F 6E2E2020 506C6561 73652073  49.77...(62092.9  is on.  Please s
0B0: 656E6420 7265706F 7274730D 6F6E2074  272.92879:9.77.:  end reports.on t
0C0: 68652065 61736520 6F662063 6F707920  42.2092.73.178<.  he ease of copy
0D0: 6F662074 686520                      73.:42.            of the
PACSAT-1>AMSAT:2-26-91

AO-16 is in Experimentor Mode until about 0500Z on
2-28-91.  The raised COSINE transmitter is on (437.050),
and the S-band transmitter is on.  Please send reports
on the ease of copy of the



000: A6A882A8 AAA600A0 8286A682 A80303F0  STATUS.PACSAT..x  ................
010: 876FCC27 8000001E B0187701 00000000  C7f.@...X.;.....  .o.'......w.....
020: 06083C05 00FB0000                    .....}..          ..<.....
PACSAT-1>STATUS:


000: 98A6A882 A84000A0 8286A682 A80303F0  LSTAT .PACSAT..x  .....@..........
010: 4920503A 30783135 4344206F 3A30206C  $.(..<..!".7...6  I P:0x15CD o:0 l
020: 3A313535 3820663A 31353538 2C20643A  ......3.......2.  :1558 f:1558, d:
030: 31207374 3A350D                      ..9:...           1 st:5.
PACSAT-1>LSTAT:I P:0x15CD o:0 l:1558 f:1558, d:1 st:5


000: 8484A6A8 82A800A0 8286A682 A81903F0  BBSTAT.PACSAT..x  ................
010: 4F70656E 20412020 203A2057 4239414E  '827. .....+!. '  Open A   : WB9AN
020: 51204B38 544C2020 204E3841 4D202020  (.%.*&...'. &...  Q K8TL   N8AM
PACSAT-12>BBSTAT:Open A   : WB9ANQ K8TL   N8AM


000: A8929A8A 404002A0 8286A682 A80303F0  TIME  .PACSAT..x  ....@@..........
010: 5048543A 20757074 696D6520 69732030  ($*..:8:462.49..  PHT: uptime is 0
020: 33352F32 303A3232 3A34392E 20205469  ..............*4  35/20:22:49.  Ti
030: 6D652069 73205468 75204665 62203238  62.49.*4:.#21...  me is Thu Feb 28
040: 2030323A 34393A33 39203139 39310D20  ................   02:49:39 1991.
PACSAT-1>TIME-1:PHT: uptime is 035/20:22:49.  Time is Thu Feb 28 02:49:39 1991


000: 8484A6A8 82A800A0 8286A682 A81903F0  BBSTAT.PACSAT..x  ................
010: 4F70656E 20412020 203A204B 38544C20  '827. .....%.*&.  Open A   : K8TL
020: 20205742 31484255 204E3841 4D202020  ..+!.$!*.'. &...    WB1HBU N8AM
PACSAT-12>BBSTAT:Open A   : K8TL   WB1HBU N8AM

000: A8989A40 404000A0 8286A682 A80303F0  TLM   .PACSAT..x  ...@@@..........
010: C36FCC27 005D019B 02560366 0468059B  a7f....M.+.3.4.M  .o.'.]...V.f.h..
020: 06680767 085B098E 0AA30B99 0CE90DDB  .4.3.-.G.Q.L.t.m  .h.g.[..........
030: 0E000F32 10D31181 12011302 14AC1592  .....i.@.....V.I  ...2............
040: 168F1789 188C1984 1A8E1B89 1C7F1D8A  .G.D.F.B.G.D.?.E  ................
050: 1E221F5A 20942171 2218234B 24362547  ...-.J.8...%...#  .".Z .!q".#K$6%G
060: 26012700 28002900 2A002B00 2C002D3D  ................  &.'.(.).*.+.,.-=
070: 2E012F98 309A319A 3200331B 34AE35AB  ...L.M.M.....W.U  ../.0.1.2.3.4.5.
080: 36C737AA 38B43985 3ADE               .c.U.Z.B.o        6.7.8.9.:.
PACSAT-1>TLM:


000: 98A6A882 A84000A0 8286A682 8303F   LT .PAST.. ...@.......0: 49203A 08135 34206 A020C...<.!.7..
IP:01Co:0 020 A3535 80663 1373022064A           ...3.....2 :558f17, d0: 31074 3A5D
.9...      1s:.
PACSAT-1>LSTAT:I :0x1D :0 :55 f:170,d1 :5
```

Part D Sample WO-18 TRACE data from TNC, edited

```
000: A8929A8A 404002AE 8A848AA4 400303F0  TIME  .WEBER ..x  ....@@......@...
010: 5048543A 20757074 696D6520 69732030  ($*..:8:462.49..  PHT: uptime is 0
020: 31312F30 363A3234 3A32312E 20205469  ..............*4  11/06:24:21.  Ti
030: 6D652069 73205468 75204665 62203238  62.49.*4:.#21...  me is Thu Feb 28
040: 2030333A 32363A35 38203139 39310D20  ................   03:26:58 1991.
WEBER-1>TIME-1:PHT: uptime is 011/06:24:21.  Time is Thu Feb 28 03:26:58 1991


000: A6A882A8 AAA600AE 8A848AA4 400303F0  STATUS.WEBER ..x  ............@...
010: 8278CC27 00000084 B0187701 00FBEFFF  A<f....BX.;..}w.  .x.'......w.....
020: 07093C05 8E000000                    ....G...          ..<.....
WEBER-1>STATUS:éx▙'ä w        <Ă

000: AE9E8886 904000AE 8A848AA4 400303F0  WODCH .WEBER ..x  .....@......@...
010: 574F443A 32362032 37203238 20323920  +'".............  WOD:26 27 28 29
020: 32412032 420D                        . ..!.            2A 2B.
WEBER-1>WODCH:WOD:26 27 28 29 2A 2B


000: 98A6A882 A84000AE 8A848AA4 400303F0  LSTAT .WEBER ..x  .....@......@...
010: 4920503A 30783134 4337206F 3A30206C  $.(..<..!..7...6  I P:0x14C7 o:0 l
020: 3A353839 3720663A 36313238 2C20643A  ......3.......2.  :5897 f:6128, d:
030: 30207374 3A300D                      ..9:...           0 st:0.
WEBER-1>LSTAT:I P:0x14C7 o:0 l:5897 f:6128, d:0 st:0


000: A8929A8A 404002AE 8A848AA4 400303F0  TIME  .WEBER ..x  ....@@......@...
010: 5048543A 20757074 696D6520 69732030  ($*..:8:462.49..  PHT: uptime is 0
020: 31312F30 363A3234 3A33312E 20205469  ..............*4  11/06:24:31.  Ti
030: 6D652069 73205468 75204665 62203238  62.49.*4:.#21...  me is Thu Feb 28
040: 2030333A 32373A30 38203139 39310D20  ................   03:27:08 1991.
WEBER-1>TIME-1:PHT: uptime is 011/06:24:31.  Time is Thu Feb 28 03:27:08 1991


000: AE9E8840 404000AE 8A848AA4 400303F0  WOD   .WEBER ..x  ...@@@......@...
010: 4764C827 00000000 00005164 C8270000  #2d.......(2d...  Gd.'......Qd.'..
020: 00000000 5B64C827 00000000 00006564  ....-2d.......22  ....[d.'......ed
030: C8270000 00000000 6F64C827 00000000  d.......72d.....  .'......od.'....
040: 00007964 C8270000 00000000 8364C827  ..<2d.......A2d.  ..yd.'.......d.'
050: 00000000 00008D64 C8270000 00000000  ......F2d.......  .......d.'......
060: 9764C827 00000000 0000A164 C8270000  K2d.......P2d...  .d.'.......d.'..
070: 00000000 AB64C827 00000000 0000B564  ....U2d.......Z2  .....d.'.......d
080: C8270000 00000000 BF64C827 00000000  d......._2d.....  .'.......d.'....
090: 0000C964 C8270000 00000000 D364C827  ..d2d.......i2d.  ...d.'.......d.'
0A0: 00000000 0000DD64 C8270000 00000000  ......n2d.......  .......d.'......
0B0: E764C827 00000000 0000F164 C8270000  s2d.......x2d...  .d.'.......d.'..
0C0: 01000000 FB64C827 00000000 00000565  ....}2d........2  .....d.'.......e
0D0: C8270000 00000000 0F65C827 00000000  d........2d.....  .'.......e.'....
0E0: 00001965 C8270000 00000000 2365C827  ...2d........2d.  ...e.'......#e.'
0F0: 00000000 00002D65 C8270000 00000000  .......2d.......  ......-e.'......
100: 3765C827 00000000 0000               .2d.......        7e.'......
WEBER-1>WOD:Gd▙'Qd▙'[d▙'ed▙'od▙'yd▙'âd▙'id▙'ùd▙'íd▙' d▙'▙d▙'┐d▙'▙d▙'▙d▙' d▙' d▙' d▙' d▙'e▙'e▙'e▙'
#e▙'-e▙'7e▙'

000: 98A6A882 A84000AE 8A848AA4 400303F0  LSTAT .WEBER ..x  .....@......@...
010: 4920503A 30783134 4337206F 3A30206C  $.(..<..!..7...6  I P:0x14C7 o:0 l
020: 3A353839 3720663A 36313238 2C20643A  ......3.......2.  :5897 f:6128, d:
030: 30207374 3A300D                      ..9:...           0 st:0.
WEBER-1>LSTAT:I P:0x14C7 o:0 l:5897 f:6128, d:0 st:0


000: A8989A40 404000AE 8A848AA4 400303F0  TLM   .WEBER ..x  ...@@@......@...
010: C878CC27 0070017E 026C038C 0475059D  d<f..8.?.6.F.:.N  .x.'.p.~.l...u..
020: 06720794 08780944 0AA50BA5 0CCE0DBC  .9.J.<.".R.R.g.^  .r...x.D........
030: 0E080F72 10B0118E 1206136B 14A915A2  ...9.X.G...5.T.Q  ...r.......k....
040: 16881780 187E1984 1A7C1B7F 1C7F1D8A  .D.@.?.B.>.?.?.E  .....~...||......
050: 1E281F60 2094217C 2277233E 24342546  ...0.J.>.;.....#  .(.` .!||"w#>$4%F
060: 26002700 28002901 2A002B00 2C002D34  ................  &.'.(.).*.+.,.-4
070: 2E002FA2 30A231A4 32363368 34A835AA  ...Q.Q.R...4.T.U  ../.0.1.263h4.5.
080: 36B637AA 38D339A7 3AA33B48 3CBF3DFF  .[.U.i.S.Q.$._..  6.7.8.9.:.;H<.=.
090: 3E483FD4 409E419E 42D4               .$.j O O!j        >H?.@.A.B.
WEBER-1>TLM:▙x▙'p~lîu¥rö^Hx   D
ÑÑ▙
▙^Hr Äk 6êÇ~ä||è(` ö!||"w#>$4%F&'()*+,-4./6061ñ263h4¿5 6▙7 8▙9º:ú;H<┐=>H?▙@ A B▙

000: A6A882A8 AAA600AE 8A848AA4 400303F0  STATUS.WEBER ..x  ............@...
010: C878CC27 00000084 B0187701 00FBEFFF  d<f....BX.;..}w.  .x.'......w.....
020: 07093C05 8E000000                    ....G...          ..<.....
WEBER-1>STATUS:▙x▙'ä w        <Ă
000: AE9E8840 404000AE 8A848AA4 400303F0  WOD   .WEBER ..x  ...@@@......@...
010: 4165C827 00000000 00004B65 C8270000   2d.......%2d...  Ae.'......Ke.'..
020: 00000000 5565C827 00000000 00005F65  ....*2d......./2  ....Ue.'......_e
030: C8270000 00000100 6965C827 00000000  d.......42d.....  .'......ie.'....
040: 00007365 C8270000 00000000 7D65C827  ..92d.......>2d.  ..se.'......}e.'
050: 00010000 00008765 C8270000 00000000  ......C2d.......  .......e.'......
060: 9165C827 00000000 00009B65 C8270000  H2d.......M2d...  .e.'.......e.'..
070: 00000000 A565C827 00000000 0000AF65  ....R2d.......W2  .....e.'.......e
080: C8270000 00000000 B965C827 00000001  d.......\2d.....  .'.......e.'....
090: 0000C365 C8270000 00000000 CD65C827  ..a2d.......f2d.  ...e.'.......e.'
0A0: 00000000 0000D765 C8270000 00000000  ......k2d.......  .......e.'......
0B0: E165C827 00000000 0000EB65 C8270000  p2d.......u2d...  .e.'.......e.'..
0C0: 00000000 F565C827 00000000 0000FF65  ....z2d........2  .....e.'.......e
0D0: C8270000 00000000 0966C827 00000000  d........3d.....  .'.......f.'....
0E0: 00001366 C8270000 00000000 1D66C827  ...3d........3d.  ...f.'.......f.'
0F0: 00000000 00002766 C8270000 00000000  .......3d.......  ......'f.'......
100: 3166C827 00000000 0000               .3d......         1f.'......
WEBER-1>WOD:Ae▙'Ke▙'Ue▙'_e▙'ie▙'se▙'}e▙'çe▙'æe▙'¢e▙'Ñe▙'»e▙'▙e▙'|e▙'═e▙'╪e▙'ße▙' e▙' e▙'e▙'
f▙'f▙'f▙''f▙'1f▙'

000: AE9E8840 404000AE 8A848AA4 400303F0  WOD   .WEBER ..x  ...@@@......@...
010: 3B66C827 00000000 00004566 C8270000  .3d......."3d...  ;f.'......Ef.'..
020: 00000000 4F66C827 00000000 00005966  ....'3d.......,3  ....Of.'......Yf
030: C8270000 00000000 6366C827 00000000  d.......13d.....  .'......cf.'....
040: 00006D66 C8270000 00000000 7766C827  ..63d.......;3d.  ..mf.'......wf.'
050: 00000000 00008166 C8270000 00000000  ......@3d.......  .......f.'......
060: 8B66C827 00000000 00009566 C8270000  E3d.......J3d...  .f.'.......f.'..
070: 00000000 9F66C827 00000000 0000A966  ....O3d.......T3  .....f.'.......f
080: C8270000 00000100 B366C827 00000000  d.......Y3d.....  .'.......f.'....
090: 0000BD66 C8270000 00000000 C766C827  ..^3d.......c3d.  ...f.'.......f.'
0A0: 00000000 0000D166 C8270000 00000000  ......h3d.......  .......f.'......
0B0: DB66C827 00000000 0000E566 C8270000  m3d.......r3d...  .f.'.......f.'..
0C0: 00000000 EF66C827 00000000 0000F966  ....w3d.......||3  .....f.'.......f
0D0: C8270000 00000000 0367C827 00000000  d........3d.....  .'.......g.'....
0E0: 00000D67 C8270000 00000000 1767C827  ...3d........3d.  ...g.'.......g.'
0F0: 00000000 00002167 C8270000 00000000  .......3d.......  ......!g.'......
100: 2B67C827 00000000 0000               .3d......         +g.'......
WEBER-1>WOD:;f▙'Ef▙'Of▙'Yf▙'cf▙'mf▙'wf▙'üf▙'ïf▙'òf▙'ƒf▙' f▙'|f▙'▙f▙'▌f▙'═f▙'█f▙' f▙' f▙' f▙'g▙'
g▙'g▙'!g▙'+g▙'

000: 98A6A882 A84000AE 8A848AA4 400303F0  LSTAT .WEBER ..x  .....@......@...
010: 4920503A 30783134 4337206F 3A30206C  $.(..<..!..7...6  I P:0x14C7 o:0 l
020: 3A353839 3720663A 36313238 2C20643A  ......3.......2.  :5897 f:6128, d:
030: 30207374 3A300D                      ..9:...           0 st:0.
WEBER-1>LSTAT:I P:0x14C7 o:0 l:5897 f:6128, d:0 st:0


000: A8929A8A 404002AE 8A848AA4 400303F0  TIME  .WEBER ..x  ....@@......@...
010: 5048543A 20757074 696D6520 69732030  ($*..:8:462.49..  PHT: uptime is 0
020: 31312F30 363A3235 3A34312E 20205469  ..............*4  11/06:25:41.  Ti
030: 6D652069 73205468 75204665 62203238  62.49.*4:.#21...  me is Thu Feb 28
040: 2030333A 32383A31 38203139 39310D20  ................   03:28:18 1991.
WEBER-1>TIME-1:PHT: uptime is 011/06:25:41.  Time is Thu Feb 28 03:28:18 1991


000: A8989A40 404000AE 8A848AA4 400303F0  TLM   .WEBER ..x  ...@@@......@...
010: D278CC27 0072017F 026D038E 047605A0  i<f..9.?.6.G.;.P  .x.'.r...m...v..
020: 06740796 08780945 0AA50BA5 0CCE0DBC  .:.K.<.".R.R.g.^  .t...x.E........
030: 0E080F72 10B0118D 1205136A 14A915A2  ...9.X.F...5.T.Q  ...r.......j....
040: 16881781 187D1984 1A7D1B83 1C7E1D88  .D.@.>.B.>.A.?.D  .....}...}...~..
050: 1E281F60 2095217C 2278233C 2432252F  ...0.J.>.<......  .(.` .!||"x#<$2%/
060: 26002700 28002900 2A002B00 2C002D2A  ................  &.'.(.).*.+.,.-*
070: 2E002FA2 30A331A4 32363368 34A935AA  ...Q.Q.R...4.T.U  ../.0.1.263h4.5.
080: 36B637A9 38D439AF 3AA23B48 3CBB3DFF  .[.T.j.W.Q.$.]..  6.7.8.9.:.;H<.=.
090: 3E483FD3 409E419F 42D4               .$.i O O!j        >H?.@.A.B.
WEBER-1>TLM:▀x▛'rmĂvátû^Hx    E
ÑÑ▼
▀^Hr ìj 6êü}ä}~ê(` ò!||"x#<$2%/&'()*+,-*./60ú1ñ263h4 5 6▌7 8▙9»:6;H<¶=>H?▙@ AƒB▙

000: A6A882A8 AAA600AE 8A848AA4 400303F0  STATUS.WEBER ..x  ............@...
010: D278CC27 00000084 B0187701 00FBEFFF  i<f....BX.;..}w.  .x.'......w.....
020: 07093C05 8E000000                    ....G...          ..<.....
WEBER-1>STATUS:▀x▛'ä w        <Ä
```

```
000: AE9E8840 404000AE 8A848AA4 400303F0  WOD   .WEBER ..x  ...@@@......@...
010: 3567C827 00000000 00003F67 C8270000  .3d........3d...  5g.'......?g.'..
020: 00000000 4967C827 00000000 00005367  ....$3d.......)3  ....Ig.'......Sg
030: C8270000 00000000 5D67C827 00000000  d........3d.....  .'......]g.'....
040: 00006767 C8270000 00000000 7167C827  ..33d.......83d.  ..gg.'......qg.'
050: 00000000 00007B67 C8270000 00000000  ......=3d.......  ......{g.'......
060: 8567C827 00000000 00008F67 C8270000  B3d.......G3d...  .g.'.......g.'..
070: 00000000 9967C827 00000000 0000A367  ....L3d.......Q3  .....g.'.......g
080: C8270000 00000000 AD67C827 00000000  d.......V3d.....  .'.......g.'....
090: 0000B767 C8270000 00000000 C167C827  ..[3d.......`3d.  ...g.'.......g.'
0A0: 00000000 0000CB67 C8270000 00000000  ......e3d.......  .......g.'......
0B0: D567C827 00000000 0000DF67 C8270000  j3d.......o3d...  .g.'.......g.'..
0C0: 00000000 E967C827 00000000 0000F367  ....t3d.......y3  .....g.'.......g
0D0: C8270000 00000000 FD67C827 00000000  d.......~3d.....  .'.......g.'....
0E0: 01000768 C8270000 00000000 1168C827  ...4d........4d.  ...h.'.......h.'
0F0: 00000000 00001B68 C8270000 00000200  .......4d.......  .......h.'......
100: 2568C827 00000000 0000               .4d.......        %h.'......
WEBER-1>WOD:5g▙'?g▙'Ig▙'Sg▙']g▙'gg▙'qg▙'{g▙'àg▙'Åg▙'Ög▙'úg▙'¡g▙'▆g▙'┴g▙'▆g▙'▛g▙' g▙' g▙' g▙' g▙'h
▙'h▙'▙'%h▙'

000: AE9E8840 404000AE 8A848AA4 400303F0  WOD   .WEBER ..x  ...@@@......@...
010: 2F68C827 00000000 00003968 C8270000  .4d........4d...  /h.'......9h.'..
020: 00000000 4368C827 00000000 01004D68  ....!4d.......&4  ....Ch.'......Mh
030: C8270000 00000000 5768C827 00000000  d.......+4d.....  .'......Wh.'....
040: 00006168 C8270000 00000000 6B68C827  ..04d.......54d.  ..ah.'......kh.'
050: 00000000 00007568 C8270000 00000000  ......:4d.......  ......uh.'......
060: 7F68C827 00000000 00008968 C8270000  ?4d.......D4d...  .h.'.......h.'..
070: 00000000 9368C827 00010000 00009D68  ....I4d.......N4  .....h.'.......h
080: C8270000 00010000 A768C827 00000000  d.......S4d.....  .'.......h.'....
090: 0000B168 C8270000 00000000 BB68C827  ..X4d.......]4d.  ...h.'.......h.'
0A0: 00000000 0000C568 C8270000 00010000  ......b4d.......  .......h.'......
0B0: CF68C827 00000000 0000D968 C8270000  g4d.......l4d...  .h.'.......h.'..
0C0: 00000000 E368C827 00000000 0000ED68  ....q4d.......v4  .....h.'.......h
0D0: C8270000 00000000 F768C827 00000000  d.......{4d.....  .'.......h.'....
0E0: 00000169 C8270001 00000000 0B69C827  ...4d........4d.  ...i.'.......i.'
0F0: 00000000 00001569 C8270000 00000000  .......4d.......  .......i.'......
100: 1F69C827 00000000 0000               .4d.......        .i.'......
WEBER-1>WOD:/h▙'9h▙'Ch▙'Mh▙'Wh▙'ah▙'kh▙'uh▙'h▙'ëh▙'ôh▙'¥h▙'ºh▙'▓h▙'▆h▙'┼h▙'╧h▙'┘h▙' h▙' h▙' h▙'i▙
'i▙'i▙'i▙'

000: 98A6A882 A84000AE 8A848AA4 400303F0  LSTAT .WEBER ..x  .....@......@...
010: 4920503A 30783134 4337206F 3A30206C  $.(..<..!..7...6  I P:0x14C7 o:0 l
020: 3A353839 3720663A 36313238 2C20643A  ......3.......2.  :5897 f:6128, d:
030: 30207374 3A300D                      ..9:...           0 st:0.
WEBER-1>LSTAT:I P:0x14C7 o:0 l:5897 f:6128, d:0 st:0


000: A8929A8A 404002AE 8A848AA4 400303F0  TIME  .WEBER ..x  ....@@......@...
010: 5048543A 20757074 696D6520 69732030  ($*..:8:462.49..  PHT: uptime is 0
020: 31312F30 363A3235 3A35312E 20205469  ..............*4  11/06:25:51.  Ti
030: 6D652069 73205468 75204665 62203238  62.49.*4:.#21...  me is Thu Feb 28
040: 2030333A 32383A32 38203139 39310D20  ................   03:28:28 1991.
WEBER-1>TIME-1:PHT: uptime is 011/06:25:51.  Time is Thu Feb 28 03:28:28 1991


000: A8989A40 404000AE 8A848AA4 400303F0  TLM   .WEBER ..x  ...@@@......@...
010: DC78CC27 00720181 026C0392 047005A3  n<f..9.@.6.I.8.Q  .x.'.r...l...p..
020: 06730797 08750948 0AA50BA5 0CCE0DBB  .9.K.:.$.R.R.g.]  .s...u.H........
030: 0E080F72 10B0118E 1205136A 14A915A3  ...9.X.G...5.T.Q  ...r.......j....
040: 16861780 187E1984 1A7E1B86 1C7E1D88  .C.@.?.B.?.C.?.D  .....~...~...~..
050: 1E281F60 2098217C 22772343 2433252C  ...0.L.>.;.!....  .(.` .!||"w#C$3%,
060: 26002700 28012900 2A002B00 2C002D2D  ................  &.'.(.).*.+.,.--
070: 2E002FA3 30A231A3 32363366 34A935AA  ...Q.Q.Q...3.T.U  ../.0.1.263f4.5.
080: 36B637A9 38D439B7 3AA23B48 3CBB3DFF  .[.T.j.[.Q.$.]..  6.7.8.9.:.;H<.=.
090: 3E483FD4 409E419E 42D4               .$.j O O!j        >H?.@.A.B.
WEBER-1>TLM: x▛'rülÆpúsù^Hu   H

▜^Hr Ăj úåÇ~ä~~ê(`  !||"w#C$3%,&'()*+,--./ú061ú263f4 5 6▌7 8▙9▖:6;H<▜=>H?▙@ A B▙

000: A6A882A8 AAA600AE 8A848AA4 400303F0  STATUS.WEBER ..x  ............@...
010: DC78CC27 00000084 B0187701 00FBEFFF  n<f....BX.;..}w.  .x.'......w.....
020: 07093C05 8E000000                    ....G...          ..<.....
WEBER-1>STATUS: x▛'ä w        <Ă
```

```
000: AE9E8840 404000AE 8A848AA4 400303F0  WOD   .WEBER ..x  ...@@@......@...
010: 2969C827 00000000 00003369 C8270000  .4d........4d...  )i.'......3i.'..
020: 00000000 3D69C827 00000000 00004769  .....4d.......#4  ....=i.'......Gi
030: C8270000 00000000 5169C827 00000000  d.......(4d.....  .'......Qi.'....
040: 00005B69 C8270000 00000000 6569C827  ..-4d.......24d.  ..[i.'......ei.'
050: 00000000 00006F69 C8270000 01000000  .......74d.......  ......oi.'......
060: 7969C827 00000000 00008369 C8270000  <4d.......A4d...  yi.'.......i.'..
070: 00000000 8D69C827 00000000 00009769  ....F4d.......K4  .....i.'.......i
080: C8270000 00000000 A169C827 00000000  d.......P4d.....  .'.......i.'....
090: 0000AB69 C8270001 00000000 B569C827  ..U4d.......Z4d.  ...i.'.......i.'
0A0: 00000000 0000BF69 C8270000 00000000  ......_4d.......  ........i.'......
0B0: C969C827 00000000 0000D369 C8270000  d4d.......i4d...  .i.'.......i.'..
0C0: 00000000 DD69C827 00000000 0000E769  ....n4d.......s4  .....i.'.......i
0D0: C8270000 00000000 F169C827 00000000  d.......x4d.....  .'.......i.'....
0E0: 0000FB69 C8270000 00000100 056AC827  ..}4d........5d.  ...i.'.......j.'
0F0: 00000000 00000F6A C8270000 00000000  .......5d.......  .......j.'......
100: 196AC827 00010000 0000               .5d.......        .j.'......
WEBER-1>WOD:)i╚'3i╚'=i╚'Gi╚'Qi╚'[i╚'ei╚'oi╚'yi╚'âi╚'ii╚'ùi╚'íi╚' i╚'╡i╚'┐i╚'╔i╚'╙i╚' i╚' i╚' i╚'
i╚'j╚'j╚'j╚'

000: AE9E8840 404000AE 8A848AA4 400303F0  WOD   .WEBER ..x  ...@@@......@...
010: 236AC827 00000000 0000               .5d.......        #j.'......
WEBER-1>WOD:#j╚'

000: 8682A6A8 404000AE 8A848AA4 400303F0  CAST  .WEBER ..x  ....@@......@...
010: 0D0A4665 62203234 2C203139 39310D0A  ..#21...........  ..Feb 24, 1991..
020: 41727261 7920574F 44207374 61727465   990<.+'".9:09:2  Array WOD starte
030: 64203139 32305554 430D0A74 6F646179  2.....**!..:720<  d 1920UTC..today
040: 2E202057 696C6C20 62656769 6E20786D  ...+466.12347.<6  .  Will begin xm
050: 69742074 6F6D6F72 726F772E 0D0A0D0A  4:.:767997;.....  it tomorrow.....
060: 37332773 20574133 5053440D 0A200D0A  ...9.+ .()".....  73's WA3PSD.. ..
070: 0D0A0D0A 0D0A                        ......            ......
WEBER-1>CAST:

Feb 24, 1991

Array WOD started 1920UTC

today.  Will begin xmit tomorrow.



73's WA3PSD




000: 98A6A882 A84000AE 8A848AA4 400303F0  LSTAT .WEBER ..x  .....@......@...
010: 4920503A 30783134 4337206F 3A30206C  $.(..<..!..7...6  I P:0x14C7 o:0 l
020: 3A353839 3720663A 36313238 2C20643A  ......3.......2.  :5897 f:6128, d:
030: 30207374 3A300D                      ..9:...           0 st:0.
WEBER-1>LSTAT:I P:0x14C7 o:0 l:5897 f:6128, d:0 st:0
```

Part E Sample LO-19 TRACE data from TNC after the BBS operational, edited

```
000: A6A882A8 AAA60098 AAA682A8 400303F0  STATUS.LUSAT ..x  ............@...
010: DA72CC27 8000001E B018AA01 02000000  m9f.@...X.U.....  .r.'............
020: 090B3C05 00B40000                    .....Z..          ..<.....
LUSAT-1>STATUS:rr▌'Ç   <┤

000: 8484A6A8 82A80098 AAA682A8 401903F0  BBSTAT.LUSAT ..x  ............@...
010: 4F70656E 20414220 443A2057 4239414E  '827. !."..+!. '  Open AB D: WB9AN
020: 5120                                 (.                Q
LUSAT-12>BBSTAT:Open AB D: WB9ANQ

000: A8929A8A 40400298 AAA682A8 400303F0  TIME  .LUSAT ..x  ....@@......@...
010: 5048543A 20757074 696D6520 69732030  ($*..:8:462.49..  PHT: uptime is 0
020: 31372F30 303A3231 3A30312E 20205469  ..............*4  17/00:21:01.  Ti
030: 6D652069 73205468 75204665 62203238  62.49.*4:.#21...  me is Thu Feb 28
040: 2030333A 30333A35 31203139 39310D20  ................   03:03:51 1991.
LUSAT-1>TIME-1:PHT: uptime is 017/00:21:01.  Time is Thu Feb 28 03:03:51 1991

000: 829A82A4 8E400098 AAA682A8 400303F0  AMARG .LUSAT ..x  .....@......@...
010: 0D466562 2032342E 0D0D5765 20657870  .#21......+2.2<8  .Feb 24...We exp
020: 6572696D 656E7420 4E4F2042 524F4144  294627:.''.!)' "  eriment NO BROAD
030: 43415354 206F6E20 5765646E 65736461  ! )*.77.+2272920  CAST on Wednesda
040: 792E0D41 6C6C2042 42532070 6572666F  <.. 66.!!).82937  y..All BBS perfo
050: 726D616E 63652072 65706F72 74732077  960712.92879:9.;  rmance reports w
060: 696C6C20 62652061 70726563 69617465  466.12.0892140:2  ill be apreciate
070: 642E0D0D 37332064 65206E70 204C5537  2......22.78.&*.  d...73 de np LU7
080: 5841430D 414D5341 54204152 47454E54  , !. &) *. )#"'*  XAC.AMSAT ARGENT
090: 494E410D 0D                          $' ..             INA..
LUSAT-1>AMARG:
Feb 24.

We experiment NO BROADCAST on Wednesday.
All BBS performance reports will be apreciated.

73 de np LU7XAC
AMSAT ARGENTINA


000: 98A6A882 A8400098 AAA682A8 400303F0  LSTAT .LUSAT ..x  .....@......@...
010: 4920503A 30783134 4337206F 3A30206C  $.(..<..!...7...6  I P:0x14C7 o:0 l
020: 3A313634 3520663A 31373631 2C20643A  ......3.......2.  :1645 f:1761, d:
030: 31207374 3A350D                      ..9:...           1 st:5.
LUSAT-1>LSTAT:I P:0x14C7 o:0 l:1645 f:1761, d:1 st:5


000: AE847282 9CA2E098 AAA682A8 407924F0  WB9ANQpLUSAT <.x  ..r.........@y$.
010: FD006475 6C652074 68652043 57204265  ~.2:62.:42.!+.!2  ..dule the CW Be
020: 61636F6E 2020696E 20746865 206E6561  0177..47.:42.720  acon  in the nea
030: 720D0A66 75747572 652E2020 49732020  9..3:::92...$9..  r..future.  Is
040: 6973206E 6F202073 6F206561 73792020  49.77..97.209<..  is no  so easy
050: 61732063 68616E67 65202074 6F205458  09.140732..:7.*,  as change  to TX
060: 2D422020 746F2054 582D412E 20205468  .!..:7.*,. ...*4  -B  to TX-A.  Th
070: 65204357 20426561 636F6E0D 0A696E63  2.!+.!20177..471  e CW Beacon..inc
080: 6C756465 206D6563 68616E69 63616C20  6:22.6214074106.  lude mechanical
090: 206D6F76 656D656E 74202861 20205245  .67;2627:..0..)"   movement (a  RE
0A0: 4C415920 77697468 20206C61 74636829  & ,.;4:4..60:14.  LAY with  latch)
0B0: 2E202049 74202064 6973636F 6E6E6563  ...$:..249177721  .  It  disconnec
0C0: 74207468 650D0A52 61697365 6420436F  :.:42..)04922.!7  t the..Raised Co
0D0: 73696E65 2066726F 6D207468 6520616E  9472.3976.:42.07  sine from the an
0E0: 74656E61 20616E64 20636F6E 6E656374  :270.072.177721:  tena and connect
0F0: 20746865 20435720 54582E20 54686174  .:42.!+.*,..*40:   the CW TX. That
100: 206D6561 6E732074 68617420 746865    .62079.:40:.:42    means that the
LUSAT-12>WB9ANQ: dule the CW Beacon  in the near

future.  Is  is no  so easy  as change  to TX-B  to TX-A.  The CW Beacon

include mechanical  movement (a  RELAY with  latch).  It  disconnect the

Raised Cosine from the antena and connect the CW TX. That means that the
```

Appendix E

Construction and Alignment Notes

General construction notes

1) Use sockets for all ICs.
2) Order at least 1 extra of each chip, it is cheap insurance.
3) The copper on the circuit boards oxidize, be sure to buff the copper side with 00 steel wool or sandpaper before soldering.
4) These are generally analog circuits, use the same power supply to tune and operate. I spent a great deal of time trying to figure out why one project would work on the bench, but not at the operating location.
5) I have included a schematic for a very simple, general purpose RS232 - TTL/CMOS interface. I highly recommend this for any project needing an RS232 interface. The interface is based upon the MAXIM 232 chip. One of its best features is that you need only supply +5v, it generates the +10v and -10v needed for RS-232. The chips are available from JDR Microdevices, Jameco and other sources.
6) While taking frequency measurements with a frequency counter, you notice the values jumping around quite a bit, here are 2 hints.
    a) use a scope probe
    b) add a resistor in series to reduce reflections

==

G3RUH 400 bps PSK Demodulator construction notes

Read the general construction notes above.

There is great deal of difference among the 4046 chips. I recommend that you buy 4 or 5 extra. So when you are unable to bring the VCO to the required frequency, you can to just substitute another 4046 rather than unsolder and change a capacitor/resistor.

Be careful in unsoldering components, I had some problems with traces coming off of the board when I removed some components.

The unit needs 175 - 200 mV of signal to work well.

The modification by Ed Krome, KA9LNV in the July 1990 issue of The AMSAT Journal is very helpful in tuning in the signal. It adds LEDs for both the CLOCK LOCK and CARRIER LOCK signals. It is also easier to add this feature as you are building the unit initially.

This demodulator needs some type of driver for RS232 levels and data sense. The data and DCD values need to be inverted before converted to RS232 levels. Included is a schematic to perform both operations.

Connect up the BLOCK DATA circuit, even if you think you don't need it. The unit will function using only a 2 wire serial cable, but the P3C program needs the BLOCK DATA line. You will want to use this program eventually.

G3RUH 400 bps PSK Demodulator Tuneup procedure

To do the job right you need:	AO-13 PSK test tape Voltmeter audio signal generator frequency counter

Get the test tape from AMSAT-NA. You will cause yourself quite a bit of grief if you don't have a good quality, correctly tuned AO-13 PSK tape to check out the unit.

Very generally this unit uses comparators to do many of the functions. There are three basic steps to aligning the unit.

A - set a reference voltage for the comparators.
B - set an 800 Hz bandwidth around 1600 Hz for carrier recovery
C - align the 400 Hz clock.

A. Center the comparator voltage
  1) Measure the power supply voltage.
  2) Calculate half this voltage
  3) Place your volt meter on U1 pin 14 and ground and adjust VR2 for the voltage calculated in step #2.

B. Align the VCO for 800 Hz bandwidth around 1600 Hz
  1) Place the frequency counter on Tp1.
  2) Place the fine tuning pot(VR3) to center rotation .
  4) Supply Vcc at pin 9 of IC3 (4046) or at J2-4, read the frequency and adjust VR2 for approximately 2000 Hz. This is 400 HZ above 1600 Hz baseline.
  5) Supply GND at pin 9 of IC3 or at J2-4 and read the frequency. Adjust VR2 for 1200 Hz. This is 400 Hz below the 1600 Hz center frequency.
  6) Repeat steps 4 and 5 until you get approximately an 800 Hz swing between the measurement at Vcc and at GND.

C. Align the 400 Hz clock
  1) Place the frequency counter on Tp2.
  2) Adjust VR4 until you get exactly 400 Hz. It is important to get this exactly 400 Hz as the bandwidth is very narrow, 1-2 Hz.

==

G3RUH 1200 bps AFSK Demodulator notes

Read the general construction notes at the beginning.

There is great deal of difference among the 4046 chips. I recommend that you buy 4 or 5 extra. So when you are unable to bring the VCO to the required frequency, you can to just substitute another 4046 rather than unsolder and change a capacitor/resistor.

Be careful in unsoldering components, I had some problems with traces coming off of the board when I removed some components.

Hook the data out to pin 3 of a 25 pin D shell connector. Then run a straight through serial cable (3 - 3 , 7 - 7) to your computer.

The unit aligns very easily, just follow the instructions. This unit has worked extremely well for me. Remember that you need a strong, constant signal for this demodulator to work well. This must be done with a gain antenna, correct tracking, pre-amp and good coax.

===================================

TAPR 1200 baud PSK modem

Read the general construction notes at the beginning.

Put the unit in a box large enough to give you some room to operate.

The explaination/drawing of the USB/LSB switch hookup are inconsistent in the assembly instruction, see the article by Jim White in March 1990 AMSAT Journal.

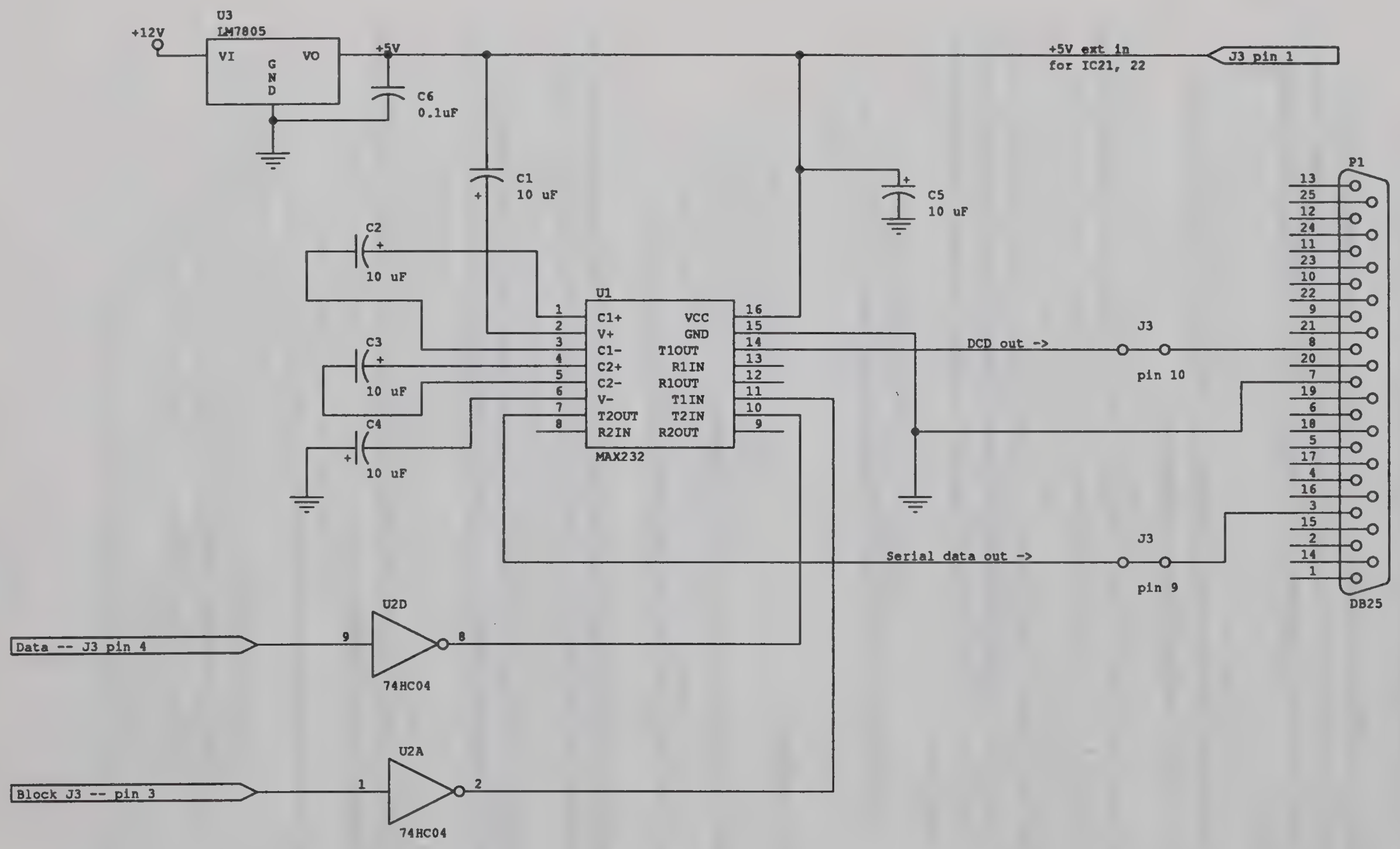
This unit works very well, the alignment went just as described in the manual. It took me about 9 hours to assemble, an hour for the cables and an hour and a half to tune.

See articles by Ross Forbes, Lyle Johnson, and Jim White listed in the General Telemetry References in the Bibliography.

==

JDR Microdevices
2233 Branham Lane
San Jose, CA 95124
800 538-5001

Jameco Electronics
1355 Shoreway Road
Belmont, CA 94002
(415) 592-8097
($50 minimum order)



U1 MAX232
U2 74HC04
U3 LM7805
C1 - C5 10uF electro 16V
C6 0.1uF
P1 DB25 connector female

A modem cable can be used with this configuration.

Required connection: 3 - 3, 7 - 7, 8 - 8.

Gould Smith				
Title	G3RUH AO13 PSK RS232 Mod			
Size A	Document Number			REV
Date: October 1, 1990		Sheet	1 of	1

Bibliography

General Telemetry References

Daviddoff, Martin, "Satellite Experimenters' Handbook",ARRL, 1982

Daviddoff, Martin, "Satellite Experimenters' Handbook",ARRL, 1990

Duncan, Courtney, N5BF, "Toward the Future in the Amateur Satellite Program Next Steps in the Ground Segment", "Proceedings of the AMSAT-NA Sixth Space Symposium and Annual Meeting", 1988

Forbes, Ross W., WB6GFJ, "Using the G3RUH 1200 Baud PSK Modem with the PK-232", "The AMSAT Journal", March 1990

Hardman, Gordon, KE3D, "The Integrated Housekeeping Unit-A Method of Telemetry, Command and Control for Small Spacecraft", "AMSAT-NA Technical Journal", Volume 1, No. 2, Winter 1987-88

Johnson, Lyle, WA7GXD, "The TAPR PSK Modem", "QEX", September 1987

Kasser, Joe, W3/G3ZCZ, "Telemetry - The Best Kept Secret", "The AMSAT Journal", August 1989

Kasser, Joe, W3/G3ZCZ, "A Proposed Standard for Packetized Telemetry", "The AMSAT Journal", July 1990

Kasser, Joe, W3/G3ZCZ, "Telemetry:Our Greatest Asset", "The AMSAT Journal", September 1990

King, J.A., et. al., "The In-Orbit Performance of Four Microsat Spacecraft", "The AMSAT Space Symposium Proceedings", AMSAT-NA, October 1990

Miller, J.R., G3RUH, "Decoding OSCAR Telemetry, Part 1", "73 Amateur Radio", May 1989

Miller, J.R., G3RUH, "Decoding OSCAR Telemetry, Part 2", "73 Amateur Radio", June 1989

Miller, J.R., G3RUH, "Helical Antennas for 435 MHz", "Electronics and Wireless World", June 1985

Underwood, Craig, G1WTW, "Ionising Radiation Effects Upon Spacecraft Microelectronics", "Proceedings of the AMSAT-UK Colloquium '90", AMSAT-UK, 1990

Ward, Jeff, G0/K8KA, "Experimental OSCARs", "73 Amateur Radio", May 1989

White, Jim, WD0E, "Construction of the Tucson Amateur Packet Radio (TAPR) Phase Shift Keying Modem", "The AMSAT Journal", March 1990

RS-10/11 References

Berglund, Keith, WB5ZDP, "Amateur Satellites", "World Radio", April 1990

Dzekevich, Joe, K1YOW, "Getting Started With Amateur Radio Satellites", "The AMSAT Journal", August 1989

Limebear, RWL, G3RWL,"RS10-11 Tech Data Manual",AMSAT-UK

Riportella, Vern (Rip), WA2LQQ, "New Russian Satellite Sparks Surge of Interest,Part 1,2 & 3", "The ARRL Satellite Anthology", pg 92-95, ARRL, 1988

UO-11 References

Diersing, Robert J., N5AHD, "Microcomputer Systems for UoSat Tracking and Data Acquisition", "Proceedings of the Fourth AMSAT Space Symposium", 1986
"Processing UoSat Whole-Orbit Telemetry Data", "Proceedings of the Fourth AMSAT Space Symposium", 1986

Diersing, Robert J., N5AHD, "UoSATs: The British Connection Part 1 & 2", "73 Amateur Radio", May, June 1988

Forbes, Ross, WB6GFJ, "Using the G3RUH 1200 Baud PSK Modem with the AEA PK-232", "The AMSAT Journal", May 1990

Merrman, Michael L., G0/PA3BHF, " Packetised Data Formats on the UoSAT Spacecraft", "The Proceedings of the AMSAT-UK Colloquium '90", AMSAT-UK, 1990

Merrman, Michael L., G0/PA3BHF, "The UoSAT FADSOFT Operating System and Packetized Data", "The Proceedings - Data Space 1989", AMSAT-UK, 1989

Miller, James, G3RUH, "Data Decoder for UOSAT", "Wireless World", May 1983

Roe, Pete, G0DLJ, "Building and Using the G3RUH 1200 Baud Modem", "OSCAR NEWS", AMSAT-UK, June 1990

Sodja, Howard, W6SHP, "Telemetry Reception With the PK 232", "OSCAR NEWS", AMSAT-UK, August 1990; also "The AMSAT Journal", September 1990

Sweeting, Martin, et. al., "UoSAT Spacescraft Data Booklet", University of Surrey, June 1987 UoSAT-OSCAR-11", AMSAT-UK, July 1985

unknown,"Computer Applications in Station Control and Processing for UoSAT-OSCAR-9 and and UOSAT-OSCAR-11", AMSAT-UK, July 1985

AO-13 References

Krome, Ed, KA9LNV, "Modifications to the G3RUH 400 Baud Telemetry Demodulator", "The AMSAT Journal", July 1990

Limebear, RWL, G3RWL,"AMSAT-UK OSCAR 13 Operations and Technical Handbook", AMSAT-UK, 1989

Limebear, RWL, G3RWL,"AMSAT-UK OSCAR 10 Operations and Technical Handbook", AMSAT-UK, 1984

Miller, James, G3RUH, "Oscar-13 Whole Orbit Data", "AMSAT-UK OSCAR NEWS", June 1989

Miller, James, G3RUH,"Telemetry Decoder for OSCAR-10", "Electronics and Wireless World", October and November 1984

Miller, J.R., G3RUH, "A PSK Telemetry Decoder for OSCAR-10","Ham Radio Magazine", Apr 1985

Sodja, Howard, W6SHP, "Telemetry Reception With the PK 232", "OSCAR NEWS", AMSAT-UK, August 1990; also "The AMSAT Journal", September 1990

UO-14 References

Branegan, John, GM4IHJ, "Low Budget UoSAT-OSCAR-14 9600 Baud Reception", "The AMSAT Journal"

Kasser, Joe, W3/G3ZCZ, "The UoSAT-OSCAR 14 and 15 Spacecraft", "The AMSAT Journal", May 1990

Meerman, Michael L.J., G0/PA3BHF, "The UoSAT FADSOFT Operating System and Packetized Data", "DATA SPACE 1989 The Proceedings", AMSAT-UK,1989

Miller, J.R., G3RUH, "9600 Baud Packet Radio Modem Design", Papers of the ARRL 7th Computer Networking Conference, Oct 1988

Miller, J.R., G3RUH, "A 9600 Baud Packet Radio Modem", Proceedings of the First RSGB Data Symposium, Harrow, England, AMSAT-UK, July 1988

Ward, Jeff, G0/K8KA, "Amateur Satellite Communications", "QST",July 1990

Ward, Jeff, G0/K8KA, "Amateur Satellite Communications", "QST",August 1990

Ward, Jeff, G0/K8KA, "UO-14 PCE Telemetry Format", file PCETLM.DOC on CIS HAMNET, 1990

Microsat References

AMSAT team, "Six for the Price of One, or OSCAR Count Reaches 19", "The AMSAT Journal", March 1990

Bonsall, Charles, et. al., "WEBERSAT Operations and Experiment Results", "The AMSAT Space Symposium Proceedings", AMSAT-NA, October 1990

Clark, Tom, W3IWI, et. al.,"The First Flock of MicroSats", "The AMSAT Journal", May 1989

Clark, Tom, W3IWI, "AMSAT's MICROSAT/PACSAT Program", "Proceedings of the AMSAT-NA Sixth Space Symposium and Annual Meeting", ARRL, 1988

Duncan, Courtney, N5BF, "The AMSAT-NA Microsats","73 Amateur Radio", May 1989

Jansson, Dick,WD4FAB, "Antennas for Microsat Ground Stations", "The AMSAT Journal", March 1990

Reed, John C., W6IOJ, "Microsat Decoder", "QEX", September 1990

Sodja, Howard, W6SHP, "Lindenblad Antennas for Microsat Omnidirectional Reception", "The AMSAT Journal", July 1990

White, Jim, WD0E, "Microsat Motion and Stabilization (and why we care about it)", "The AMSAT Journal", September 1990

Williams, Chris,WA3PSD, "A Brief User's Manual for Webersat's Ancillary Experiments", CAST, Weber State University, 1990

FO-20 References

JR1NVL, J.A.R.L. Control Station, "The Telemetry Formats of JAS-1b/Fuji-OSCAR 20", "The AMSAT Journal", September 1990

Kasser, Joe, W3/G3ZCZ, The Fuji-OSCAR 20 Spacecraft", "The AMSAT Journal", July 1990

Miller, J.R., G3RUH, "A Packet Radio PSK Modem for JAS-1/FO-12", "Ham Radio Magazine", Feb 1987

unknown,"Introduction of JAS-1b", "OSCAR NEWS", AMSAT-UK, December 1989

AO-21 References

ANS-328.04, 1990

ANS-328.05, 1990

Gowen, Pat, G3IOR, "RS-14 (Radio-M1 and RUDAK-2) Information", "OSCAR News", AMSAT-UK, December 1990

Kuhlen, Hanspeter, DK1YQ, (English translation by Don Moe, DJ0HC/KE6MN),"Radio-M1, The RUDAK-2 Experiment of AMSAT-U-ORBITA and AMSAT-DL", "AMSAT-DL Journal", March 1990

unknown, information from AMSAT-U, RC2CA/DB2OS, 11/11/90

RS-12/13 References

$ANS-019.03, 1991

Telemetry Glossary

A-ANT	Analog Antenna (FO20)
A/D	Analog to Digital Converter - device that converts an analog value to a digital value
ACS	Attitude Control System (UO11) - the system to control the attitude or orientiation of the satellite
ADC	Analog to Digital Converter device that converts an analog value to a digital value
ADCS	Attitude Determination, Control & Stabilisation System (UO11) comprising the sun sensors, earth horizon sensors, magnetometer and ACS
AFSK	Audio Frequency Shift Keying - method of encoding data by shifting between different audio frequencies. UO11 uses 1200 Hz = 0, 2400 Hz
AGC	Automatic Gain Control
analog	a mechanism in which data is represented by continuously variable physical quantities
APD	Antenna Power Divider (FO20)
arm	one of the three arms of the phase III satellelites. (AO13)
array	photovoltaic array - the solar cells (AO13)
ASCII	American Standard Code for Information Interchange, 127 character codes for control functions (CR, LF, FF), upper and lower case letters, numbers, and special characters (like punctuation).

BAT	battery (AO13)
BCR	Battery Charge Regulator - the part of the satellite system that manages the power generation, storage and dispersal.
BIAS	a force applied to a device in order to establish a reference level for the operation of that device. (Microsats)
BP	baseplate - floor of one of the modules. (Microsats)
bps	bits per second, baud also refers to the number of bits per second
BUS	a path or number of parallel paths over which information is transmitted. (AO13)

C	unsigned count 0 to +255 (AO13)
CCD	Charged Coupled Device - the camera imaging device, the part of a camera that converts the received image to digital values
CDM-8	(FO20)
CHANS	channels (UO11)
checksum	error detecting scheme that adds/EORs the characters to increase data reliability
CMD	command
CRC	Cyclic Redundancy Check - error detecting algorithm to increase data reliability
Cs	signed count (-128 to +127, 2's complement) (AO13)
CUR	current (Microsats)
Cx	signed count modified +63 to -192; 3Fh = +63, FFh = -1, 80h = -128, 7Fh = -129, 40h = -192 (AO13)

D-ANT	Digital Antenna (FO20)
D.ANT	Digital Translator (FO20)
DCE	Digital Communication Experiment - packet (UO11, Microsats)
DCM	Digital Communications Module (FO20)
DDEM	Digital Demodulator (FO20)
demodulator	device that removes information from a carrier. For telemetry - a device that converts tone or phase shifts to digital values.
digital	binary values (1's and 0's)
Diary	UO-11 operating system - the computer program that schedules the operation of each of the satellite functions
DISC	discriminator. A device that converts frequency or phase variations to amplitude variations. (Microsats)
DSR	Digital Store and Readout Experiment (UO11) Used to store and send WOD, CCD pictures, particle and wave experiment data.

EB	Engineering Beacon (AO13)
EC	Electron Spectrometer Experiment (UO11)
EDAC	Error Detection And Correction - circuits to find and correct errors in the system RAM
En	exponential form, * 10^n
ES	Earth Sensor (AO13)
EXT	external (Microsats)

facet	The face or one side of a satellite. The sides resemble jewel facets.

GASFET	Gallium ArSenide Field Effect Transistor. A transistor controlled by voltage rather than current. (AO13)
GB	General Beacon (AO13)

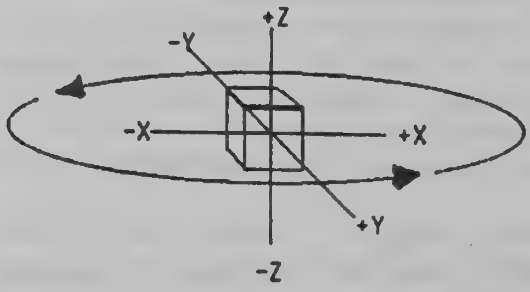
HDLC	High Level Data Link - a digital data transmission protocol
hex	hexadecimal, base 16 numbers.
Horizon Sensors	IR photocells pointing through a small angle used to detect an edge. Light in one sensor and dark in the other signal the horizon. (UO11)
HPA	High Power Amplifier (Microsats)
I	current (AO13)
increment	number of degrees of that a satellite moves on consecutive passes, normally West.
I/O	Input/Output. Used to refer to data coming into and going out of the computer.
IR	InfraRed
IHU	Integrated HouseKeeping Unit (AO13) - the onboard computer
IPS	AO13 multitasking operating system

JA	Mode J Analog - voice (FO20)
JD	Mode J Digital - PSK packet (FO20)
JAD	full Mode J, both JA and JD modes active (FO20)
JRX	J mode Reciever (FO20)

JTA	J mode analog transponder (FO20)
JTD	J mode digital transponder (FO20)
L	light (AO13)
LHCP	Left Hand Circular Polarization
LIU	Liquid Ignition Unit, AO13 motor spark plug
LO	Local Oscillator used by the receiver mixer. (Microsats)
LX	mode L transponder (AO13)
M-SOLL	(AO13) magnet vector desired angle to despun sun, CW from top, 1 circle = 256 (AO13)
magnetorquers	electro-magnets in satellites used in conjunction with the earth's magnetic field to alter the satellites attitude
Manchester	digital encoding method in which a state change (0 -> 1 or 1 -> 0) at mid bit time determines the bit value
modem	Modulator/Demodulator - a device that both modulates a carrier with information and extracts that information from a carrier.
NAVMAG	navigation magnetometer (UO11)
NBFM	Narrow Band Frequency Modulation
NRZ	Non Return to Zero, serial data encoding format
NRZI	Non Return to Zero Inverted, serial data encoding format
OBC	On Board Computer
P/W	Particle Wave Correlator Experiment (UO11)
PCB	Printed Circuit Board
PCE	PACSAT Communication Experiment - open access, Mode J, packet store and forward system using 9600 bps FSK on uplink and downlink. (UO14, Microsats)
PCM	Power Conditioning Module regulates the +14v bus to +10v, +5v and -10v needed by the different systems and experiments. (UO11)
PCU	Power Conditioning Unit (FO20)
PDM	Power Distribution Module switches power to the different modules and experiments. (UO11)
PDS	Power Distribution System (UO11)
PHT	PACSAT Housekeeping Telemetry, the housekeeping part of the microsat operating system (Microsats)
Pn	solar panel n, where n is the number of the panel.
protocol	the organization of how two or more devices transfer digital data
PSK	Phase Shift Keying - method of sending digital data by shifting the phase of the carrier
PWC	Particle Wave Correlator Experiment (UO11)
R-ANT	Recieve Antenna (FO20)
RC	Raised Cosine - method of generating PSK modulation
REF	reference (Microsats)
RHCP	Right Hand Circular Polarization

RUDAK	German acronym for Regenerating Transponder for Digital Amateur Communication
RX	receiver
S	AO13 separation buss, 14v buss supplies torquer and LIU
SDE	Space Dust Experiment (UO11)
sensor	device that measures an analog value and converts it to a digital value
SERI	Solar cell experiment (AO13)
SEU	Sensor Electronics Unit (AO13)
SEU	Single event upset, memory error (Microsats, UO-14)
SS	Sun Sensor (UO11, AO13)
ST	Transponder Separation buss (AO13)
Sun Sensors	Grey-coded solar cells used to determine the angle to the sun. (UO11)
T	Temperature (AO13), T = (C -127) / 1.182 deg C
TBA	To Be Advised, unknown at the present time will be defined later
TC	Thermocouple (AO13) - device to convert temperature to a digital value
TLM	telemetry
TVT	Telemetry Voice Transmitter module (DO17)
TX	transmitter
U	AO13 voltage label
Uad	A/D input voltage (AO13)
uptime	the total time that the current software has been running (Microsats)
UVC	(FO20)
UX	AO13 mode U (B) transponder
WASH	cleaning out of the SEU (single event upset) buffer, correcting the edac (error dectecting and correcting ram (Microsats, UO-14)
WOD	Whole Orbit Data - data from selected channels stored for an entire orbit
Z	AO13 mA designation

General satellite axis labels:



Appendix H

Checksums

Checksums are necessary in digital communication because important data needs some type of validation. Noise bursts, signal fading, or signal collisions all cause the data bits to be misinterpreted. I will quickly look at some of the more common methods.

Parity

This is one of the simplest forms of checksums. One bit is added to the serial character stream for parity. Parity is either NONE, EVEN, ODD, SPACE, or MARK. The biggest problem with parity error checking is that it is only 40% effective in error detection. If more than one bit is affected the parity is often fooled. Parity is also bit intensive, one bit/character is needed.

NONE means that the bit is not added.
EVEN Parity says that the number of 1 bits in the character + the parity bit will be an even number. The ASCII letter 'C' (43h) has a bit pattern of 0100 0011. There are 3 ones so the parity bit would be a 1 to make the total 4, or an even number.
ODD Parity says that the number of 1 bits in the character + the parity bit will be an odd number. Using the letter 'C' again (0100 0011) with 3 ones in its ASCII code. The parity bit will be 0, since there are already an odd number of one bits.
SPACE Parity says that the parity bit will always be a 0.
MARK Parity will always have a 1 for the parity bit.

CRC (Cyclic Redundancy Checks)

CRC's are an extremely powerful method of error detection. These checks are made over a block of data, so only 1 or 2 bytes (8 or 16 bits) are added to the data stream. CRC checks are especially good at detecting errors that occur in bursts over a relatively long time.

Here are some promises for a 16 bit CRC:

Single bit errors:	100%
Double bit errors:	100%
Odd numbered errors:	100%
Burst errors shorter than 16 bits:	100%
Burst errors of 17 bits:	99.9969%
All other burst errors:	99.9984%

CRC-CCITT

The CRC-CCITT is used by both AO-13 and UO-14. Essentially the data block is considered as one long bit stream. This large value is then divided by some magic number. The remainder is then used for the CRC checksum. This magic number is derived from the polynomial:

$$X^{16} + X^{12} + X^{5} + 1.$$

The first CRC checksums were done in hardware using XOR gates to perform the division. Now they are implemented in software by a microprocessor. IBM employed this checksum method for its first floppy disk controller, the Model 3770. It quickly became a standard for microprocessor disk controllers and is now used on IBM's popular synchronous protocol HDLC/SDLC (High-level Data Link Control/Synchronous Data Link Control).

Here is a general explanation of the algorithm from the "AMSAT-UK OSCAR-13 Operations and Technical Handbook".

```
1. Initailise two byte CRCC register to #FFFF
2. Take each incoming bit and calculate:
   IF (RXBIT EXOR CRCC_MSBIT) <> 0 THEN FBACK = #1021 ELSE
   FBACK = 0 CRCC = ((‾ * 2) AND #FFFF) EXOR FBACK
3. Do step 2. for all 514 received bytes (512 bytes + 2 CRC)
4. IF CRCC = 0 THEN BLOCK = OK ELSE BLOCK = NOT OK
```

```
RXBIT        FBACK
---->(+)-------->----+-------------->-----------+----->---------+
      |    H         |           L    H         |           L   |
      |   +-----+    |    +-------+  +-----+    |    +-------+  |
      +-<-| | | |<--(+)<--| | | | |<-| | | |<--(+)<--| | | | |<-+
          +-----+    |    +-------+  +-----+    |    +-------+  |
          <------- CRCC MSB ------>  <----- CRCC  LSB ------->
```

Figure H.1 sample C code for XMODEM CRC as used on UO-14

The XMODEM CRC receive checking is defined using the following C code:

```
unsigned short crc;          /* global crc register.               */
crc = 0;                     /* clear crc register                 */
for (all received data bytes)
    gen_crc(rx_byte);        /* crc the incoming data bytes        */
gen_crc(1st_crc_byte);       /* crc the incoming first crc byte    */
if(gen_crc(2nd_crc_byte))    /* crc the incoming second crc byte   */
        bad_crc();           /* non-zero crc reg. is an error      */
else
        good_crc();          /* zero crc is a good packet.         */

/* Function to take a byte and run it into the XMODEM crc generator.   */
/* Uses a global CRC register called "crc".                            */
gen_crc(data)
char data;
{
    int y;
    crc ^= data << 8;
    for(y=0; y < 8; y++)
        if( crc & 0x8000)
            crc = crc << 1 ^ 0x1021;
        else
            crc <<= 1;
    return crc;
}
```

CRC-16 is another widely used CRC polynomial. It is not quite as efficient at catching errors as the CRC-CCITT. The popularity of CRC-16 is due chiefly to its long history in IBM's BYSYNC protocol. The CRC-16 uses different polynomial:

$$X^{16} + X^{15} + X^{2} + 1$$

==

Further information on CRC checksums is available in:
"C Programmer's Guide to Serial Communications" by Joe Campbell, Howard W. Sams and Co., 1987 and BYTE Magazine, September 1986, pp. 115-124.

Appendix I

Product sources

AMSAT-NA
850 Sligo Ave.
Suite #600
Silver Spring, MD 20910
(301) 589-6062

AO-13/Microsat test tape
Jack Mathais, W9FMW 400 baud PSK telemetry decoding software
TLMDC software, Microsat binary decoding software
SIMPLE14.EXW UO-14 telemetry decoding software
N5AHD UO-11 decoding software
Numerous satellite tracking programs

==

AMSAT-UK
94 Herongate Road
Wanstead Park
London E12 5EQ England
[AT&T] 011 44 81 989-6741

UoSat-11 FSK demodulator printed circuit board (PCB)
G3RUH 400 baud PSK demodulator PCB
G3RUH 1200 baud PSK modem PCB
AMSAT-UK OSCAR-13 Operators Handbook
UoSAT-2 Data Handbook
P3C.EXE software to be used with G3RUH 400 baud PSK demodulator
DTLM software by K8KA to decode UO-11 & UO-14 packetized telemetry
SATSCAN software - EGA satellite tracking software
"OSCAR NEWS" with AMSAT-UK membership

==

L.L. Grace Communications Products
41 Acadia Drive
Voorhees, NJ 08043
(609) 751-1018

Kansas City Tracker, rotor control software/hardware
DSP-12 Multi-mode Communications Controller

==

Kasser, Joe, G3ZCZ
PO Box 3419
Silver Spring, MD 20918

WHATS-UP software to decode DOVE and FO-20 telemetry
LAN-LINK software to control your TNC

==

PacComm
3652 West Cypress St.
Tampa, FL 33607
(813) 874-2980

PSK-1 combination 1200 baud modem/400 baud PSK demodulator unit
9600 baud modem

==

Project OSCAR, Inc.
P. O. Box 1136
Los Altos, CA 94023-1136

P3C.EXE software for the G3RUH 400 baud PSK demodulator
AO-13 RTTY W6SHP telemetry decoding program

==

RadioKit
P. O. Box 973-C
Pelham, NH 03076
(603) 635-2235

G3RUH 1200 baud modem kit
WB5IPM printer port antenna controller

==

TAPR (Tucson Amateur Packet Radio)
P. O. Box 12925
Tucson, AZ 85732
(602) 749-9479

1200 baud PSK modem kit
K9NG 9600 baud modem kit
PK232 modem disconnect upgrade kit
IBM plug-in DSP board

==

Telemetry Archive

Once you have collected telemetry data and looked at it, what do you do with it? You may be one of the few or the only person to collect telemetry for that satellite at that particular time. You may have unknowingly captured an important event. Rather that have the telemetry data spread around the world in many different formats, AMSAT-NA has undertaken to centralize this telemetry data. It is important for engineers, researchers and educators to have access to as complete a data set as possible. Reid Bristor has generously volunteered to collect and organize telemetry from the amateur satellites. So become a frequent contributor to this important endeavor.

Soon their will be an awards program in place to recognize consistent and regular contributors to this amateur satellite telemetry archive.

Send your collected telemetry data or requests for data to:

Reid Bristor, WA4UPD
4535 Deerwood Trail
Melbourne, Florida 32935

The following information was supplied by Reid Bristor.

Telemetry requests
If you are interested in historical data on a particular satellite, send your request to Reid with:

1) pre-paid mailer with sufficient return postage; and
2) sufficient media (from the following media list) to hold the information requested.

Any requests for information concerning the archive should contain a business size SASE.

Telemetry submissions
All types of amateur satellite telemetry are accepted. Currently only telemetry in raw (KISS) data format is archived, DOVE ASCII data is included. Any other telemetry format submissions will be retained, but will not become part of the 'online' archives. This means that data submitted that is not in raw KISS format will be retained, but will not be readily available. Those interested in historical data should follow the instructions in the 'telemetry request' section. Telemetry may also be submitted to Reid's BBS (300/1200/2400) by special request.

Address the request to SYSOP at
(407) 242-9866, M - F 6pm - midnight
Sat - Sun noon - midnight

Telemetry Archive Information

Submission format

Media format: IBM 5 1/4", 180k, 360k, 1.2m
IBM 3 1/2", 770k, 1.44m
COMMODORE 1541, 1571, 1581
DEC RX01/02, RX50, TK50

File format: 1 file per pass

FILENAME - mmddhhmm.ssx
- mm = Month (02 = FEB, 05 = MAY, 11 = NOV, etc.)
- dd = Day (correct UTC day)
- hh = Hour of AOS (UTC)
- mm = Minute of AOS
- ss = Satellite Number (ex. 17 for DOVE)
- x = data type (see below)
  - A = ASCII (DOVE, ASCII text, N4HY dump)
  - C = CW (RS-10/11, LUSAT, FO-20, AO-13)
  - P = Processed (N4HY, LU7ABF, etc)
  - R = RAW (KISS format)
  - T = Telemetry
  - V = WEBERSAT picture data

Ex. 11020212.18R is the filename for:

month 11, day 02, hour 02, minute 12, satellite 18, raw data or

raw data from WEBERSAT with AOS at 02:12 UTC NOV 11

MARCH 5, 1991

Command Station Development Program

With the increasing worldwide interest and activity in the amateur satellite program, there is a parallel demand for interested, trained, and reliable command station operators. The Command Station Development Program (CSDP) was developed to discover and prepare interested individuals to accept the important responsibilities of a command station operator.

The CSDP is not intended for newcomers to OSCAR operations. Applicants should have a firm grasp of tracking a satellite, and have assembled a reliable receiving station for one or more of the amateur satellites.

It will require a substantial investment in time and funds to assemble telemetry demodulation equipment and software for the various satellites. Few fields in amateur radio can offer such an interesting and challenging endeavor as the Command Station Development Program.

AMSAT-NA has set the following acceptance standards for applicants and participants in the CSDP:

1) Continuing membership in an AMSAT organization recognized by AMSAT-NA;

2) OSCAR operating experience; and

3) Ability to access the CompuServe dial-in BBS.

The most important asset in joining the CSDP is a genuine interest and willingness to participate. Don't let lack of equipment, knowledge, or software keep you from applying. This is a development program, equipment, knowledge and software can be acquired in time.

To obtain an application form for the CSDP, send an SASE to:

Bruce Rahn, WB9ANQ
410 Coronado Trail
Enon, OH 45323

The CSDP has 6 development levels, LEVEL-0 to LEVEL-5. Successful applicants enter the CSDP at LEVEL-0.

LEVEL-0: Familiarization phase

LEVEL-1: Growth phase

LEVEL-2: Specialization phase

OPERATIONAL LEVELS

LEVEL-3: Payload operations

LEVEL-4: Spacecraft bus systems hardware operations

LEVEL-5: Spacecraft bus systems and payload software operations

The responsibilities of LEVEL-0 (familiarization phase) are to:

A) Obtain detailed information about each operational OSCAR spacecraft;

B) Begin equipping themselves with the hardware and software necessary to receive and interpret spacecraft telemetry data;

C) Submit progress reports to the CSDP technical coordinator demonstrating the member's ability to capture and reduce spacecraft data;

D) Communicate regularly with other members of the program contributing to the success of all.

Promotion to LEVEL-1 (growth phase) will require:

(A) A demonstrated interest and capability to routinely copy and reduce telemetry data from operational OSCAR satellites.

(B) Continue developing their command station capabilities as well as their personal knowledge, understanding, and appreciation of spacecraft systems and payloads.

(C) Participate in special assignments -- such as watches of satellites of special interest, scientific experiments of various types, hardware and software development efforts, etc. commensurate with their interests and the needs of AMSAT.

(D) Continue telemetry data acquisition and reduction with emphasis on the analysis of the data.

(E) Share the results of their efforts with CSDP members, the AMSATs of the world, and the general satellite user community.

Promotion to LEVEL-2 (specialization phase)

(A) Performance demonstrating reliable and continuing interest in the health and welfare of OSCAR series spacecraft.

(b) Telemetry acquisition and analysis will have to continue for a satisfactory period and an extraordinary effort, such as publishing articles concerning spacecraft systems, presentations at symposiums and meetings, or compiled history and analysis of system performance and trends.

(C) The satellite command capabilities will be well developed and possess a well rounded knowledge, understanding, and appreciation of the inner workings of various spacecraft payloads.

(D) Become a specialist in one or more of their areas of interest.

(E) Provide support and guidance to Level-0 and Level-1 team members.

(F) Communicate and document activities in their field(s) of expertise.

(G) AMSAT and CSDP will call upon these members to support special, long term projects and programs important to the amateur satellite cause.

Levels 3, 4, and 5 are the operational levels. Team members at these levels are responsible for the operation of a spacecraft's bus systems and payloads -- both hardware and software. They are selected based on specific mission requirements and are drawn from Level-2 CSDP members, existing command station operator resources, the developers of spacecraft systems and payloads, the spacecraft owners, and individuals who demonstrated (using the same assessment criteria applied to CSDP members) long term reliability and command station capability prior to the inception of the Command Station Development Program. General responsibilities for each of the operational levels are as follows:

Level-3:	Payload operations. Some satellites, such as the Microsats, will have their own particular operational emphasis or 'payload'. These payloads may be complex scientific, engineering, communication, or educational tools in themselves and will be managed primarily by Level-3 command operators. Level-3 command station operators will not be responsible for actual satellite bus system. Examples of their duties for the microsats will be to: serve as system operators for the packet bulletin boards; upload voice messages to DOVE; utilize the capabilities of the WEBERSAT camera; as well as monitoring the overall health and performance of these payloads.
Level-4:	Spacecraft bus systems hardware operations. Level-4 command station operators will be responsible for the spacecraft-shell health and functions including power systems, RF systems, and orientation.
Level-5:	Spacecraft bus systems and payload software operations. Level-5 command station operators will be responsible for the development, operations, and maintenance of spacecraft and payload software.